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ROSWELL PRONGHORN STUDY

PREPARED BY

NEW MEXICO STATE UNIVERSITY

FOR

THE BUREAU OF LAND MANAGEMENT

FINAL REPORT

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ROSWELL PRONGHORN STUDY

FINAL REPORT TO THE
BUREAU OF LAND MANAGEMENT

for

Contract No. VA-512-RFP9-10

to

New Mexico State University

by

Dr. Volney W. Howard, Jr. Principal Investigator
Department of Fishery and Wildlife Sciences
New Mexico State University, Las Cruces.

Dr. Jerry L. Holechek
Department of Animal and Range Sciences
New Mexico State University, Las Cruces.

Dr. Rex D. Pieper
Department of Animal and Range Sciences
New Mexico State University, Las Cruces.

Subcontracts

by

Dr. Samuel L. Beasom
Ceasar Kleberg Research Foundation
Texas A & I University, Kingsville.

Dr. Katherine Green-Hammond
Ecosystem Modeling
9413 Las Calabazillas, NE
Albuquerque.

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ACKNOWLEDGEMENTS

The authors would like to express their gratitude to many individuals, ranchers and agency personnel who cooperated or assisted with data collections and provided information on livestock numbers for the 28 study pastures.

Graduate students Jeffery Bradybough and Brian Gross provided data on pronghorn behavior and off-site fence tests during the first two years of the study.

Personnel from the New Mexico Department of Game and Fish and the Roswell District, BLM assisted with data collections and necropsy of pronghorns which were sacrificed during die-offs in 3 study pastures.

Several individuals at Texas Tech University including Leslie Krysl and Brigid Hickey assisted with the cattle, sheep, and pronghorn microhistological diet analyses. Luke J. Celantano provided statistical analyses of these data.

A special thanks is extended to Alex Lara, Wildlife Technician, and to Don Ellsworth and James Freudenberger, Range Technicians for their efforts in collecting most of the field data and doing many of the mundane jobs associated with a research project of this magnitude. Their efforts were invaluable to the success of the project.

The "Task Force" members provided editorial comments to improve the manuscript.

Mrs. June Peyton and Mrs. Kristi Spence provided word-processing/typing for the final report.

INTRODUCTION

In 1940 the New Mexico Department of Game and Fish (NMDG&F) estimated pronghorn (Antilocarpa americana) numbers at 3,000 in an area west of Roswell, New Mexico, lying between the Pecos River (east) and the foothills of the Sacramento Mountains (west) and extending approximately 80 km to the north and south of US 70-380 (Fig. 1) (Walt Snyder, former Chief of Game Management, New Mexico Department of Game and Fish). Pronghorns were so plentiful that in 1938 several hundred were trapped in east-central New Mexico and transplanted in other areas of the state and to the Wichita Mountains National Wildlife Refuge in Oklahoma. During the 1920's and early 1930's the area west of Roswell, approximately 607,042 ha (1.5 million ac), was cross-fenced with net wire (Russell 1964) in order to facilitate an expanding sheep industry. By 1977 it was estimated that pronghorn numbers had declined to approximately 300 (NMDG&F population estimate) in the area enclosed by net wire fences. Bear (1969) in Colorado, Hailey et al. (1966) in West Texas, and Russell (1951) in New Mexico have described similar declines in pronghorn populations due to restrictions imposed by net wire fences on movement of pronghorns to areas providing adequate food.

Because pronghorn numbers were declining on public lands enclosed by net wire fences in east-central New Mexico, the Bureau of Land Management's (BLM) Roswell District began plans to alleviate the effects of the net wire fences located west of Roswell. In 1975 pronghorn fencing directives were issued by the

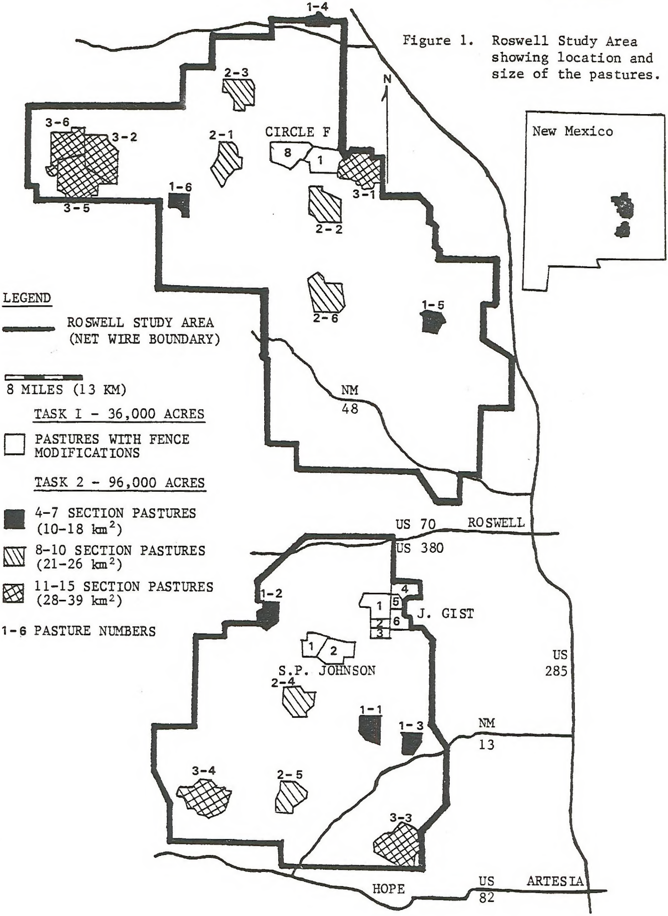


Figure 1. Roswell Study Area showing location and size of the pastures.

Roswell District, and fence modifications were initiated. Livestock ranchers, especially those situated in east-central New Mexico, objected to the federal government's policy of altering fences for pronghorns. In addition the BLM announced that pronghorns would be reestablished in historic habitat areas west of Roswell in order to comply with federal regulations which require multiple use management on public lands.

On 21 October 1976, the Federal Land Policy and Management Act (FLPMA) became law. Section 102.(a)(8) states that public land will be managed to provide food and habitat for fish, wildlife, and domestic animals. Section 103(c) defines multiple use as the management of public lands and their resources so that they are utilized in a combination that will best meet the present and future needs of the American people.

Ranchers in the area remained opposed to fencing modifications. In 1976 the BLM held several public meetings to obtain the views and recommendations of local interest groups. In the summer of 1977 a pronghorn "task force" was formed, consisting of 2 area ranchers and 2 representatives each from the BLM, NMDG&F, and the U.S. Fish and Wildlife Service. The "task force" then developed a study proposal to provide the information required to determine accurately the effects of increasing the pronghorn habitat and study any alternative means of achieving this objective.

A study was proposed by the "task force" to: 1.) study the movement of livestock and pronghorns through different sizes and types of fence modifications, and 2.) determine the botanical composition of sheep, cattle and pronghorn diets and relative preference for different plant species by these herbivores, and to develop models to characterize and predict pronghorn habitat qualities and minimum area needed to support viable pronghorn herds. A viable herd was defined as a herd where recruitment equals mortality.

Task I included 6 subtasks: 1) conduct vegetational analysis in 10 study pastures; 2) monitor pronghorn, cattle and sheep movements through 12 existing fence modificiations; 3) document behavior of pronghorns, cattle, sheep and predators in relation to fence modifications; 4) contact ranchers once each month to document their observations of livestock and pronghorn movements, behavior and reaction to fence modification; 5) document livestock and pronghorn numbers within each pasture during each month; 6) and to test various "panels" of fence for their capability to contain cattle and sheep under stress conditions. Task II included 4 subtasks: 1) conduct vegetational analysis of 18 study pastures that had pronghorns transplanted into them; 2) develop a computer model to determine variables necessary to establish minimum requirements to support a viable pronghorn herd; 3) conduct monthly censuses of pronghorns and livestock within the study pastures; and 4) make fecal collections for pronghorns, and cattle and sheep when appropriate, to determine seasonal food preference. It was anticipated that the performance period for the research would take approximately 4 years. The study was to begin no earlier than 1 December 1978, and be completed by 30 September 1982. The study contract was awarded to New Mexico State University, Agricultural Experiment Station in April 1979.

STUDY AREA

Topography

The 4-year study was conducted in 18 study pastures approximately 20 to 70 km northwest and southwest of Roswell, New Mexico (Fig. 1). This area is generally characterized as a short grass prairie with topography varying from flat prairies to rolling hills progressing to rugged limestone hills and canyons.

Vegetation

Principal grass species consist of dropseed (*Sporobolus* spp.) gramas (*Bouteloua* spp.), muhly (*Muhlenbergia* spp.), threeawns (*Aristida* spp.), windmill grasses (*Chloris* spp.), buffalograss (*Buchloe dactyloides*), and tobosa (*Hilaria mutica*). Primary perennial woody species found in the area which ranges from between 1 to 10% cover on any particular pasture, includes catclaw (*Acacia greggii*), cholla (*Opuntia imbricata*), mesquite (*Prosopis glandulosa*), oaks (*Quercus* spp.), broom snakeweed (*Gutierrezia sarothrae*), Louisiana sagewort (*A. ludoviciana*), and Apache plume (*Fallugia paradoxica*).

Climate

The climate is semiarid with abundant sunshine and wide ranges of daily and seasonal temperatures. Winter temperatures seldom reach -18°C (22°F) while summer temperatures rarely go above 38° C (100° F). The average yearly precipitation is approximately 30.5 cm (12 in) and generally falls between July and September (Maker et al. 1971).

Ranching Industry

Cattle and sheep ranching are the primary land uses for the area with most pastures being grazed year round. Some pastures were rested from livestock use at various times of the year throughout the study. Both cattle and sheep were grazed in 12 of the pastures, cattle only in 3 pastures, and sheep only in 3 pastures. Stocking rates for cattle and sheep varied from 7 to 84 ha (17 to 207 ac) (3.1-35.9 AUs/sect) per animal unit year whenever livestock were in the pastures.

METHODS

General Job Description

This study involved 2 distinct tasks conducted concurrently. Task I involved approximately 270 pronghorns on 14,569 ha (36,000 ac) to provide data on the movement of livestock and pronghorns through different sizes and types of fence modifications. Task II involved 300 pronghorns on 38,591 ha (95,360 ac) to determine the size area needed to support a viable herd of pronghorns within the study area (Fig. 1).

Task I: Fence Modifications

In Task I, 3 ranches were involved with the fence modifications. These included the J. Gist Ranch, the Circle F Ranch, and the S. P. Johnson Ranch. Pronghorn numbers on the Gist Ranch varied from 91 (2-8-80) to 367 (6-6-82). Ten fence modifications or passes (#1-10) were located on the Gist Ranch (Fig. 2) and consisted of 4- strand barbed wire and were approximately 45 to 91 m (50 to 100 yds) long. The top strand was approximately 109 cm (43 in) high and the bottom strand about

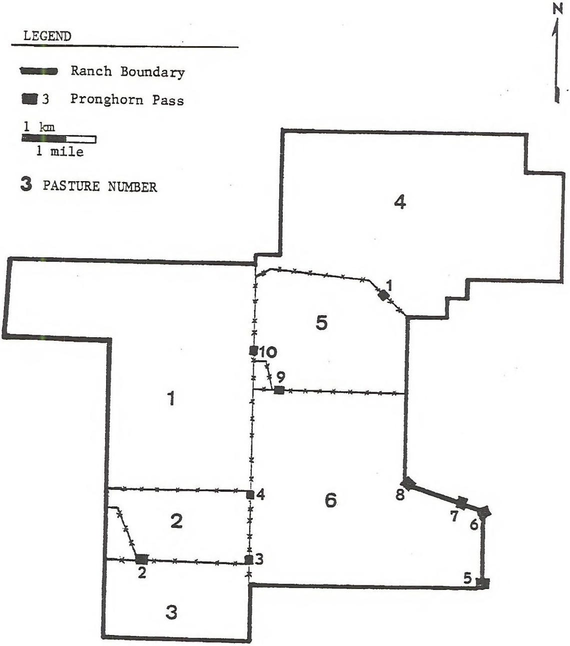


Figure 2. The James Gist Ranch showing locations of 4-strand pronghorn passes.

41 cm (16 in) above the ground. On 6 November 1980, the BLM reduced passes #2 and #5 to 3.7 m (12 ft) in length. A cattle guard-type pass was installed in place of the 4- strand barbed wire fence at pass site #2 on 12 December 1980. Passes #1, #9, and #10 were closed permanently on 12 November 1981 due to very little pronghorn use. Livestock and pronghorn use was monitored monthly by taking track counts.

Two fence modifications (#11 and #12) were located on the Circle F Ranch. Both passes were composed of 3 top strands of barbed wire and 1 bottom strand of smooth wire. The top strand was 109 cm (43 in) high and the bottom strand was 30.5 cm (12 in) off the ground. Pass #11 was about 183 m (200 yd) long while #12 was approximately 91 m (100 yd) long. There were 16 (7-6-82) to 48 (9-6-79) pronghorns on the ranch with an average of 26 for the 3 years. Both passes were monitored every month by counting tracks.

The S. P. Johnson Ranch contained a "Paul's Pass" as described by Russell (1951) (Fig. 3). Pronghorn numbers varied from 15 (7-22-81) to 37 (7-6-82) and averaged 27 for the 3 years. Pass use was monitored monthly by counting tracks.

Off-site Fence Tests

Four vertical panel structures (Fig. 4) and 1 horizontal grill (Fig. 5) were selected for tests involving livestock. These tests were conducted at New Mexico State University, Las Cruces. A standard 81.3 cm (32 in) vertical net wire fence was used as a control structure. Two 4-strand barbed wire fences were tested. The first barbed wire panel has been commonly used

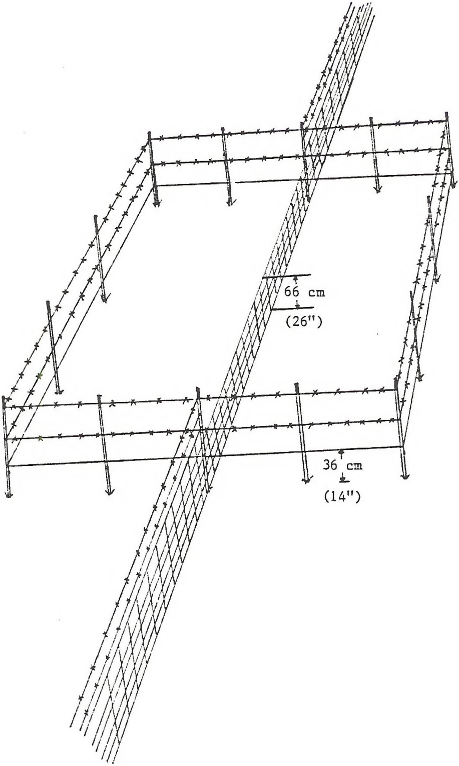
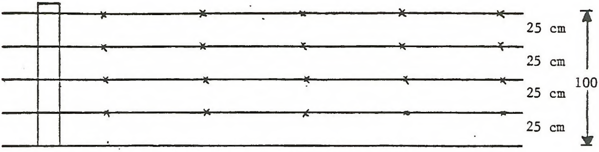
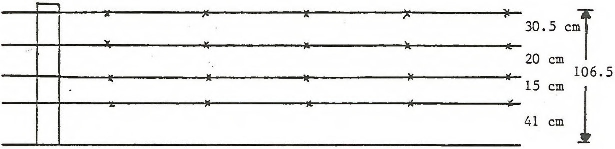


Figure 3. Diagram of fences included in "Paul's Pass" for pronghorn.

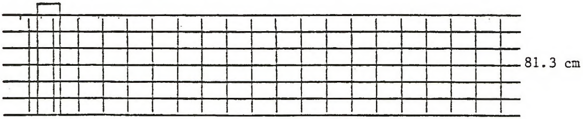
4 STRAND BARBED WIRE STANDARD (total height 40")



4 STRAND BARBED WIRE VARIATION (total height 42")



81.3 CENTIMETER NET WIRE (total height 32")



NET WIRE VARIATION (total height 50")

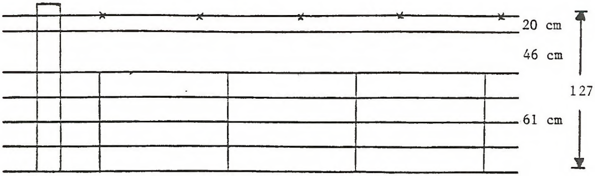


Figure 4. Characteristics of experimental antelope passes.

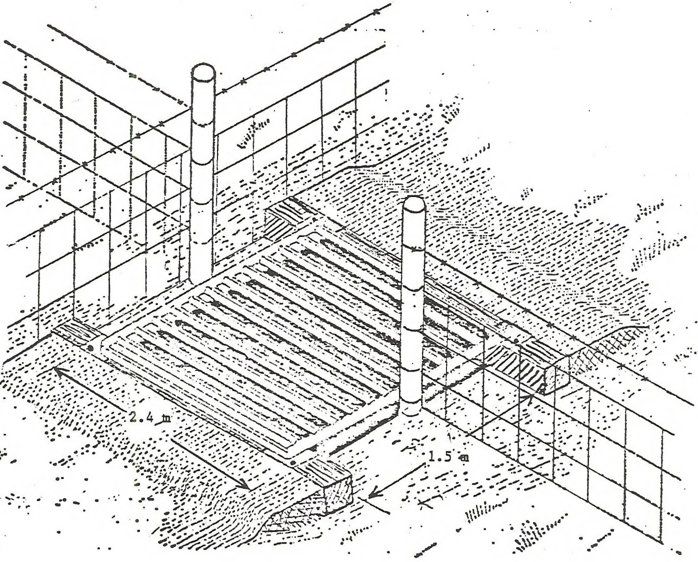


Figure 5. Characteristics of the horizontal antelope grill. (Adapted from Mapston and Zobell 1970).

by government agencies and ranchers. It consisted of 4 wire strands spaced equally at 25.4 cm (10 in) intervals from ground level. A second barbed wire structure was termed a barbed wire variation. This consisted of 4 strands, beginning at ground level, separated by distances of 40.6 cm (16 in), 15.2 cm (6 in), 20.3 cm (8 in), and 30.5 cm (12 in). Total vertical heights of the 2 barbed wire structures were approximately 1 m (40 in) and 1.1 m (42 in), respectively. A fourth panel involved the use of net wire in conjunction with 1 barbed wire strand. The net wire consisted of 4 smooth wire strands supported by equally spaced wire stays at 15-cm (6 in) intervals, extending to a vertical height of 61 cm (24 in). This structure is termed a net wire variation. A fifth smooth wire strand was placed 46 cm (18 in) above the net wire. The upper-most strand was barbed wire and was placed 20 cm (8 in) above the upper smooth wire strand. This panel extended to a total vertical height of 117 cm (46 in). A horizontal pronghorn grill (Fig. 5), developed by Mapston et al. (1970), also was tested. Construction of vertical test panels was identical in all test situations with the exception of the cow/calf tests.

For test purposes an enclosure was constructed of 1.5 x 3.7 m (5 x 12 ft) steel Powder River panels. This enclosure had a total length of 49 m (160 ft) and a total width of 9.8 m (32 ft). Five individual test paddocks equal in size were constructed within the enclosure. This allowed for the conducting of 5 independent and simultaneous trials. Each test paddock was equally sectioned into 2 subunits. These subunits were separated by individual test panels. The total length of a vertical test panel within each test paddock was 9.8 m (32 ft). A 2.1 m (7 ft) steel fence post then was placed at midpoints in each 9.8 m (32 ft) span of test fence for support purposes. In all trial situations animals under test were placed opposite to a test panel with some stress factor placed on the other side. The structure of the study enclosure allowed tests to be conducted independently and animals under stress to have maximum exposure to each test panel.

Tests of all panels were conducted using cattle and sheep. Two breeds of range cattle, Hereford and crossbred Brangus, were used, although no differentiation was made in recording results. Sheep included Rambouillet and Suffolk with no differentiation made in breed response.

Three stress situations were selected and applied to cattle and sheep. These stress situations included male-female stress, female-water stress, and female-unweaned young stress. Lambs used in the ewe-lamb trial ranged from 4 to 7 weeks of age while calves used in the cow-calf trial were approximately 3 months of age.

All tests involved the construction of test panels between paddock subunits with placement of animals opposite specific stress factors or animals opposite specific animals. The cow-calf tests involved the placement of an additional strand of barbed wire 91 cm (3 ft) from all vertical test panels on the same side of the test fence as the cow. This prevented calves from nursing through the fence. Horizontal pronghorn grill devices were placed at 1 end of each test paddock.

Each pass structure/stress situation/animal type test was replicated 10 times. Each test involved an exposure period of 24 hr with an additional stress period of 24 hr for female-water trials. Male-female trials involved the synchronization of estrus in females by the use of chemical stimulators.

Two structures which were tested using only female-water stress trials were a 96.5 cm (38 in) 3-strand structure and a 96.5 cm (38 in) 4-strand structure (Fig. 6). The specifications for the 3-strand pass included placement of a smooth bottom strand 40.6 cm (16 in) from ground level. Above this, 2 barbed wire strands were placed at 28-cm (11 in) intervals. Specifications for the 4-strand structure included placement of a smooth bottom strand 25.4 cm (10 in) from ground level. Placed above this were 3 barbed wire strands at intervals of 20.3 cm (8 in), 25.4 cm (10 in), and 25.4 cm (10 in).

The stress subsets used for testing the restriction potential of these 2 additional structures were cow/water and ewe/water separation trials.

The standard chi-square analysis was used for all statistical testing (Steel and Torrie 1960). All data were expressed as percentages of animals which crossed each type of restriction.

Task II: Capture and Transplanting Pronghorns

Pastures used in Task II of the study varied in size from about 1,000 to 3,900 ha (4 to 15 sections) all enclosed with net wire. Twenty-seven grazing allotments containing 81 pastures

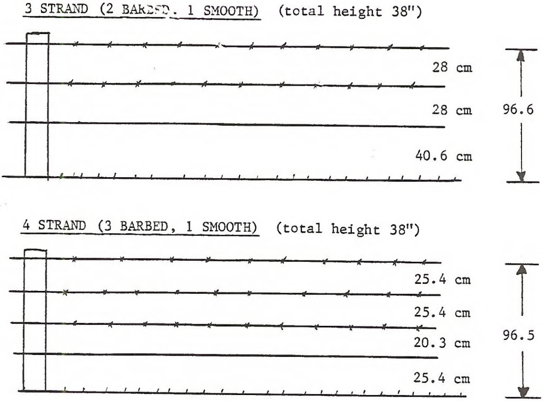

3 STRAND (2 BARBED, 1 SMOOTH) (total height 38")
28 cm
28 cm
96.6
40.6 cm
4 STRAND (3 BARBED, 1 SMOOTH) (total height 38")
25.4 cm
25.4 cm
96.5
20.3 cm
25.4 cm

Figure 6. Characteristics of experimental pronghorn passes receiving partial tests.

within the study area were considered for the study after receiving the ranchers' verbal agreements to cooperate in supplying water, maintaining fences, and furnishing actual livestock use records. All 81 pastures then were evaluated for production and variety of grasses, forbs, and browse; and diversity and suitability of topography. The 18 pastures in the study were chosen by a random selection. These pastures were divided into 3 size classes ranging from approximately 1,000 to 3,900 ha (4 to 15 sections) with 6 replications of each size (Fig. 1).

The NMDG&F, along with the BLM, captured a total of 309 pronghorns using techniques described by Russell (1964). Trapping operations began on 15 January 1979, and the last animals were released on 10 March 1979. Nine of the total 309 pronghorns were replacements for those that died during transit or shortly after release. All pastures were flown within 1 week after the release to locate the dead or injured animals for replacement purposes. State and BLM biologists examined all dead animals to determine the probable cause of death. Some of the detrimental causes were found to be stress and shock, pneumonia and 1 possible bald eagle (Haliaeetus leucocephalus) kill.

Pronghorns were stocked in each pasture at a density of 1 per 130 ha (2 per section) and at a sex ratio of 1 male per 3 females. All animals to be released into the study area were fitted with vinyl-coated nylon collars. Males received blue collars, and females received orange collars. Red, yellow, and black numbers identified the pasture and size class designation.

Aerial Censuses

Monthly inventories of pronghorn populations were conducted via aerial censuses in both tasks. Total herd numbers, natality, mortality, survival, immigration, and emigration were assessed. During April and May of each year no aerial surveys were taken to avoid disturbing the ewes or does while lambing and fawning were in progress.

Several types of airplanes were used throughout the study including a Piper Archer, Warrior Super Cub, and Cessna Cuttlass and Skyhawk. Each pasture was flown early in the morning on a north to south grid pattern with transects approximately 400-800 m apart and at an altitude of 50-100 m and airspeed of about 140 km/hr. If the total count appeared low when compared to the previous census the pasture was regridded on an east to west pattern and the higher count was recorded. After an animal had been missing for 4 months it was omitted from the population. The highest number of fawns recorded during any month for that year was accepted as being a minimum estimate of total fawns born in that pasture.

Vegetational Studies

Procedures used in the vegetation sampling followed closely the procedures for the Soil-Vegetation - Inventory Methods (SVIM) outlined by the Bureau of Land Management. Initially all the study pastures were mapped into range sites following descriptions presented by the Soil Conservation Service (1967) (Appendix 1). The size of each range site was utilized to determine the allocation of sampling units to each pasture.

Basal cover was determined by the step-point method (Evans and Love 1957). Each transect consisted of 100 points. If the basal portion of a plant fell directly beneath a small point on the tip of the observer's boot, the species was recorded. Ground cover conditions including bare ground, litter, and rock were also recorded. The step-point transects were sampled once in each pasture in the Fall of 1979 or early winter of 1980 in the same general location as the herbage standing crop transects.

Herbage standing crop was determined by the weight estimate method (Pechanec and Pickford 1937, Wilm et al. 1944) with (0.25 m^2) circular quadrats. There were 10 quadrats in each transect, but the length of the quadrat varied depending upon the size, shape, and topography of the range site. Double sampling was not used, but periodic clipping was utilized to keep weight estimates as accurate as possible. Herbage standing crop was estimated in all pastures during January, March, June, and September of each year during the study.

Fecal Collections and Diet Analysis

Fecal samples were collected for dietary studies on a seasonal basis (January, March, June, and September) for all Task II pastures and 1 Task I pasture. A sample of 12 fecal groups per species for all pastures was attempted each season. This sampling scheme resulted in total sample sizes of 2,340 for cattle; 2,184 for sheep; and 1,894 for pronghorns. Pronghorn pellets were collected only after observing animals defecating except in pastures where there were no sheep. No difficulty was encountered in identifying cattle dung. Sheep pellets were collected at watering tanks and from bedding areas. All fecal samples were collected as fresh as possible for that month. Approximately 20-30 pellets were collected for sheep and pronghorns and about 20 ml of sample was collected from individual cattle fecal passages. All samples were placed in individually marked (species, collection date, and pasture) plastic bags and soaked with 90% ethanol until analyses were performed.

Microhistological examinations (Baumgartner and Martin 1939, Dusi 1949) were conducted on each fecal group to determine the vegetative diet at the Wildlife Food Habits Analysis Laboratory, Texas Tech University, Lubbock. Fifty percent of each fecal group was emulsified in a commercial food-mixing blender, a sample transferred to 2 microscope slides, and a cover slip affixed. Systematically-located microscope fields were examined on each slide, and all plant fragments in each field were identified, based on characteristics of epidermal tissues (Croker 1959, Davis 1959), or categorized as "unknown". A reference collection of microscope slides and corresponding microphotographs was developed to facilitate this procedure. Data for each animal were recorded as relative frequencies by dividing the number of "hits" for a given plant species by the number of hits for all species.

Diet similarities, comparing species rather than general forage classes, were made using Kulczinski's Similarity Index (Oosting 1956). The resulting indices were tested for pasture and season effects. Initial data inspection indicated that the variation about the average index was symmetric and that the sizes of the seasonal ranges were similar within each comparison; therefore, the assumption that the average similarity indices were normally distributed appeared justified. The variation across season appeared homogeneous (R. King 1981, personal communication).

Pronghorn Data Set Compilation

Data collected from overflights on numbers of pronghorns in each study pasture were organized over time by dividing years into 3-month seasons beginning in March, June, September, and December. Numbers of collared males and females, uncollared males and females, and fawns at the beginning of each season in each pasture were determined from the maximum number of individuals in each category seen during the season and in subsequent months. Data from a series of flights were considered for each seasonal data point since not all animals were seen on every flight. Pronghorns which jumped out of a pasture and then returned were considered to have remained in the pasture for the purpose of enumerating surviving animals in the pasture.

Seasonal data for pronghorns were grouped into years, with each year beginning with the June through August season, the first season in which new fawns could be observed. Maximum observed fawn production for each pasture each year was the maximum number of fawns seen on an individual flight during that year. Fawns per female were calculated as the maximum number of observed fawns divided by the number of adult females alive at the end of the March to May season when fawns were born. For the first fawn crop, the number of females stocked in the pasture was used as the divisor. Yearling and adult females alive at the end of the next spring season were old enough to have produced fawns, since the yearlings were almost 2 years old during that season.

Seasonal survival rates for fawns, adult females, and adult males were calculated by dividing the number of animals alive at the end of a season by the number of animals alive at the beginning of that season.

Environmental Data Set Compilation

Descriptive information for each study pasture was tabulated and included pasture size, an index to latitude (Township designation), ruggedness index (a multiplicative function of total relief and the total length of all contour lines traversing an area, Beasom et al. 1983), vegetation type, percent of climax vegetation, SCS and SVIM estimates of annual forb, grass, and shrub production, and a dummy variate based on a BLM designation of suitability for pronghorns (good or poor).

Data for environmental variables which did vary over the course of the study were organized into 3-month seasons corresponding to those used for pronghorn population data. Stocking rates (average animal units per section for cattle and sheep) were calculated for each season based on 1 cow or 5 sheep per animal unit. The fraction of cattle and sheep that was calves and lambs also was recorded for each season. Total standing crop of grasses, forbs, and shrubs was recorded from measurements for each season. The number of forb species and the combined standing crop of preferred forbs (those with highest importance values in pronghorns' diets) also were recorded. The percentages of grasses, forbs, and shrubs in the diets of cattle, sheep, and pronghorns were tabulated for each pasture and season. Rain gauge readings were summarized to provide totals for 4 periods; 1) March through May, 2) June and July, 3) August, and 4) September through November, for each pasture each year. No precipitation data were collected for December through February.

Data Analysis

The original study design was structured for analysis of variance, with pastures grouped into 3 size ranges and divided between 2 suitability types within each size group. However, pastures within each size group were not of a uniform size, the 2 suitability types (good or poor) proved unreliable, and 3 pastures were dropped during the course of the study so that sample sizes within size groups varied. Therefore, multiple regression analysis was more suitable than the more structured analysis of variance. A dummy variate was used for suitability type, and actual pasture sizes replaced the pasture size groups in the analysis. Simple correlation coefficients were calculated between pronghorn population data and environmental data, and among environmental variables. Some calculations used seasonal data, and some used averages over several seasons, as appropriate. Dependent variables for multiple linear regressions were chosen from pronghorn population data for examining associations with environmental parameters from the same and preceeding seasons.

Because of the range of environmental variables measured during this study, there were frequently more variables than observations for any given class of regressions. Consequently, independent variables to be examined were chosen on the basis of study objectives, pronghorn life history information, and correlations with the dependent variable. Forward addition stepwise regression techniques were used to select the best subset of independent variables (Steel and Torrie 1980).

Two sets of analyses were performed with the study data. The first included only those environmental variables that did not change throughout the study and those that could reasonably have been estimated beforehand. The second included all of the seasonally varying environmental data.

RESULTS

Fence Modifications

Minimum estimated numbers of pronghorns utilizing the 4-wire passes on the James Gist Ranch (Table 1) show that certain passes (i.e. #3, #4, #5, and #8) received use on a regular basis throughout the study. Other passes received periodic use, but did not have consistent, regular use. Pass #1 was not utilized by pronghorns during the first 3 years of the study and was closed by Mr. Gist on 12 November 1982 along with #'s 9 and 10. Pass #2 which received high use in 1979 and 1980 was replaced with an "antelope guard" in December 1980 and use declined approximately 65% in the subsequent 2 years.

Table 1. Minimum numbers of pronghorns using passes on the James Gist Ranch, 1979-82.

Pass Number	Year				Total	Crossings/ Month
	1979a	1980b	1981	1982c		
1d	0	0	0	--	0	0
2e	49	40	16	14	119	3.05
3	28	83	55	96	262	6.72
4	26	54	57	54	191	4.90
5	31	71	97	80	279	7.15
6	18	29	32	18	97	2.49
7	9	11	2	28	50	1.28
8	28	73	50	58	209	5.36
9d	2	14	34	--	50	1.72
10d	1	7	18	--	26	0.90

a June through December
b February through December
c January through September
d passes closed 12 November 1981
e pass replaced with 3.6 m pronghorn guard December 1980

In 1980 Mr. Gist reported some heifers and bulls had crossed pass #9 where the barbed wire strands had broken, and 2 heifers were believed to have crossed pass #1. In June 1981 Mr. Gist reported 2 calves had crossed passes #1 and #10 and died from being separated from their mothers. In October 1981 he reported another calf had died when it was not able to return to its mother after crossing either pass #3 or #4.

The estimated numbers of pronghorns using the 4-wire passes on the Circle F were lower than on the James Gist Ranch (Table 2). The pronghorns on the Circle F Ranch were restricted to the 2 pastures adjacent to the fence with the passes. In addition, the total number of pronghorns on this ranch was considerably less than that on the James Gist Ranch (approx. 25 vs over 200).

Table 2. Minimum numbers of pronghorns using passes on the Circle F Ranch, 1979-82.

	Year					
Pass Number	1979a	1980b	1981	1982c	Total	Crossings/ Month
11	2	0	2	5	9	0.24
12	13	2	28	0	43	1.13

a June through December
b Not read in April and May
c January through September

In 1980 Mr. Sealy (Circle F Ranch) reported some bulls were jumping pass #12 and both passes had some sign of sheep crossings throughout various times of the year. Between 20 April and 20 May 1981, Mr. Sealy reported that approximately 25 ewes had crossed both passes. During that fall about 23 sheep from pasture 1 had crossed into pasture 8; and 2 cows, 2 calves, and 1 bull had crossed from pasture 8 into pasture 1.

The pass on the S. P. Johnson Ranch apparently was unused by pronghorns during the 2 years it was monitored. Numbers of pronghorns counted in the 2 pastures adjoining the pass did vary, according to the aerial censuses, but no positive evidence of pronghorns utilizing the pass was documented. If the pronghorns utilized this pass, their tracks were either obliterated by sheep tracks or erased by wind and rain before they were observed. Pronghorns possibly utilized other means to move between the 2 pastures.

During 1980 some sheep were seen on both sides of the pass and in 1981 some sign of sheep use was noted. In 1981 Mr. Troy Floyd (S. P. Johnson Ranch) reported 20 sheep were believed to have crossed the pass from pasture #2 into pasture #1. On 23 April 1981 it was decided that the pass would no longer be monitored, and aerial surveys for pronghorns would be flown only in February and September.

Off-site Fence Tests

There were no significant differences ($P>0.05$) between any of the pronghorn passes when results were summed over all livestock classes and types (Table 3). Division of results into categories of cattle and sheep indicated no significant differences ($P>0.05$) occurred between the panels for cattle but differences were significant ($P<0.05$) for sheep. The 81.3-cm (32 in) net wire control panel was superior to other passes for sheep restriction. Results from adult cattle show that the horizontal pronghorn grill was significantly better ($P<0.05$) than the 81.3-cm (32 in) net wire fence. The net wire variation was inferior to the horizontal pronghorn grill and the 4- strand barbed wire standard in the restriction of adult sheep. Both lambs and calves were completely restricted by the 81.3-cm net wire variation.

Table 3. Percentages of animals crossing each panel type. Values with different subscripts within a row were significantly different ($P<0.05$) in restrictive efficiency. Values without subscripts were not significantly different ($P>0.05$).

Category	4-strand barbed wire	Barbed wire variation	81.3-cm net wire	Net wire variation	Horizontal pronghorn grill
1 cattle	43.3	30.0	53.3	56.7	26.7
2 sheep	60.0b	70.0b	30.0a	70.0b	70.0b
3 adult cattle	40.0ab	35.0a	80.0c	70.0bc	15.0a
4 adult sheep	40.0	55.0	45.0	65.0	65.0
5 calves	50.0	20.0	00.0	30.0	50.0
6 lambs	100.0b	100.0b	00.0a	80.0b	80.0b
7 adults	40.0a	45.0ab	62.5bc	67.5c	40.0a
8 young	75.0b	60.0b	0.00a	55.0b	65.0b
9 total	51.7	50.0	41.7	63.3	48.3

Results of the tests using the additional structures (Table 4) indicate that both additional structures restricted cattle to a greater extent than sheep. Cattle were restricted with 100% efficiency by both pronghorn passes. The 3-strand pass restricted sheep with only 40% efficiency. Sheep showed the behavioral tendency to move through the structure beneath the bottom strand.

The additional 4-strand structure proved superior to the 3-strand structure because it was 90% efficient in maintaining separation of ewes from sources of water. In this trial, ewes showed a limited capability of sliding beneath the bottom strand of wire.

Table 4. Percentages of animals crossing each type of additional structures (standard BLM fences).

Livestock Class	Fence Type	
	3-strand	4-strand
Cattle	0	0
Sheep	60	10

Aerial Census

Populations of pronghorns in the 18 study pastures fluctuated throughout the study (Table 5). Most pastures showed considerable increase in numbers of pronghorns at the beginning of 1980, thus indicating high reproduction and fawn survival during the summer of 1979. The populations continued to increase in 4 pastures in 1980; but 3 pastures had very dramatic declines and were withdrawn from future studies in November 1980, thus leaving 15 pastures for the remainder of the study.

Reproduction and fawn survival was moderately high during the summer of 1981, and 10 of the 15 remaining pastures had a net increase in pronghorn populations when compared to the previous year. During the summer of 1982 fawn production and survival was highly variable. Only 3 pastures showed substantial increases in

Table 5. Populations of pronghorns in the 18 study pastures, as determined by aerial censuses, 1979-82.

Pasture Number	Year				
	1979 (Feb)	1980 (Jan)	1981 (Jan)	1982 (Jan)	1982 (Sept)
1-1	12	23	30	38	52
1-2	8	13	11	14	11
1-3	8	14	8	13	19
1-4a	8	8	4	--	--
1-5	8	10	10	12	13
1-6	8	15	12	14	8
2-1	18	26	18	16	14
2-2	16	22	18	15	15
2-3	16	25	15	11	14
2-4a	16	13	6	--	--
2-5	16	17	15	7	2
2-6	18	22	23	38	39
3-1a	22	31	0	--	--
3-2	26	35	29	49	37
3-3	22	39	45	65	78
3-4b	20	40	30	10	0
3-5	21	36	32	35	19
3-6	22	43	46	49	32

a Pasture eliminated from study November 1980
b Unknown numbers of pronghorns present in pasture at release

total pronghorn numbers. An additional pasture (3-4) had a major decline in pronghorn numbers during December 1981 and January 1982. The pronghorns in this pasture continued to decline until the June aerial census indicated the entire population had died. Subsequent flights during the remainder of the study failed to locate any pronghorns in this pasture.

At the culmination of the flights in September 1982 only 4 pastures showed substantial increases when compared to previous years of the study. All others either were stabilizing or declining in total numbers of pronghorns.

Vegetational Studies

The vegetation of the study area was primarily grassland with shrubs occurring mainly in pastures along the western side at higher elevations. Blue grama (*Bouteloua gracilis*) was the most abundant grass species, occurring in all pastures (Table 6). Three awns, mat muhly (*Muhlenbergia richardsonii*), slim tridens (*Tridens muticus*), sideoats grama (*B. curtipendula*), sand dropseed (*Sporobolus crytandrus*), and hairy grama (*B. hirsuta*) also were important in most of the pastures. Tobosa was locally abundant, occurring mostly in low-lying areas.

Forbs were not very abundant in the Fall of 1979 following a growing season which received very low precipitation.

Broom snakeweed (*Gutierrezia sarothrae*) was the most widespread shrubby species. Other shrubby species were scattered throughout the pastures.

Table 6. Basal cover (%) of plant species in study pastures at time of initial sampling (Fall 1979).

	Pasture Number																	
	1-4	1-6	2-1	2-2	2-3	2-6	3-1	3-2	3-5	3-6	1-2	2-4	2-5	3-4	1-1	1-3	1-5	1-3
Bareground	47.6	47.0	29.0	26.7	37.0	42.8	40.7	36.0	34.9	42.0	23.0	31.0	22.5	38.5	27.0	35.6	25.5	46.6
Litter -Persistent	0.3	Tr	1.0	1.0	0.3	1.3	0.3	0.5	0.2	Tr	Tr	0.3	1.0	1.3	0.3	0.2	0.8	Tr
-Nonpersistent	22.6	9.0	4.0	10.5	21.0	6.0	10.2	7.2	8.0	9.0	2.0	11.0	7.0	14.0	9.3	12.5	3.8	12.0
Gravel	4.6	4.6	6.0	12.8	3.6	6.0	8.7	3.5	7.0	4.0	17.5	8.0	8.0	5.0	16.8	10.0	7.8	8.2
Cobble	3.3	4.0	12.0	12.0	3.0	2.5	4.5	8.5	8.0	5.0	9.0	7.0	8.5	11.3	8.3	5.1	6.5	3.8
Stone	1.6	Tr	4.0	2.0	2.6	2.3	0.3	0.8	1.0	0.5	4.0	1.6	2.5	5.0	1.8	1.6	2.5	Tr
Bedrock	1.6	1.3	1.0	1.0	1.0	1.5	0.8	1.0	1.0	0.8	6.5	6.3	5.0	2.5	4.5	4.5	2.5	4.0
SPECIES																		
Grasses																		
Bouteloua gracilis	4.6	18.3	14.0	5.3	6.3	12.8	3.0	22.0	19.0	25.0	4.5	5.0	4.5	2.0	1.3	0.8	2.8	1.3
Hilaria mutica						1.8	1.8				1.5	8.3	3.0	0.8	3.5	10.5	0.8	7.2
Scleropogon brevifolius	Tr		2.0	0.8		3.3	3.5						0.5	Tr	7.3	8.1	1.5	5.8
Erioneuron pilosum	0.6	Tr	6.0	2.5		1.5	1.8	Tr	0.6		7.5	4.0	8.0	1.0	7.5	2.0	3.0	1.3
Lycurus phleoides	1.3	0.6		0.5		Tr	0.3	0.5	0.2	0.3	2.5		1.5	0.8	0.5		1.0	
Muhlenbergia repens	Tr			0.3	0.3	0.3	0.8	4.0	1.4	2.5	Tr		2.5	3.8				Tr
Muhlenbergia richardsonii	3.3	2.6	2.0	0.3	1.0	0.8	0.8	3.0	1.0	2.5	Tr		Tr	2.3	Tr	Tr	1.0	
Muhlenbergia porteri	Tr		1.0	Tr		1.5	0.8	0.3					5.5		1.8	1.7		1.2
Muhlenbergia montana								1.0	1.8		0.5		3.5	1.0				
Aristida spp.	2.3	0.6	4.0	1.5	4.3	1.0	4.0	2.0	2.6	0.3	3.5	1.3	3.0	2.0	2.0	0.7	2.8	1.3
Eragrostis intermedia			Tr								Tr	0.3	1.0	0.3				
Bouteloua eriopoda		1.0	2.0	1.3	4.3	1.8	3.0	1.3			2.5	2.0	3.0		1.5	0.7	2.5	1.3
Sporobolus cryptandrus	Tr	1.3		2.8	0.6	2.3	4.0	0.8	1.0	Tr	0.5		1.5	2.0	Tr	Tr	1.3	0.5
Sporobolus gigantea				9.3														
Stipa neomexicana	Tr	1.0	1.0	1.5	1.3	0.5		4.0	6.2	4.0							Tr	
Bouteloua hirsuta	1.6	1.0	1.0	0.5	1.6		0.5		0.4	0.3	1.0	1.0	1.5	3.3	0.5		0.8	Tr
Hilaria jamesii	0.3	0.3	1.0	0.5	0.3	4.3	1.0	3.5	2.6	4.0								
Bouteloua curtipendula	Tr	1.0	1.0	1.3	1.6		0.3	1.8	1.8	0.8	3.5	2.3	2.5	0.3	0.8	1.0	Tr	0.2
Leptochloa dubia											0.5	0.1		0.3	Tr			
Tridens muticus				0.8			Tr					Tr	Tr		1.5	0.7	0.3	0.2
Muhlenbergia torreyi	Tr	0.3		0.5	Tr	1.3	2.5				Tr				0.5	0.3	0.8	1.2
Panicum virgatum				Tr							0.5		2.0	0.3	0.3		Tr	Tr
Enneapogon desvauxii											Tr							
Bothriochloa barbinodis													1.0			0.5		
Panicum obtusum					Tr		0.3							0.5				Tr
Setaria leucophila											Tr							
Erioneuron puchellum			Tr	0.5		Tr			Tr	Tr		Tr	1.0	0.8	Tr	0.5	0.3	Tr
Sitanion hystrix														0.3				
Blepharoneuron tricholepis														0.3				
Andropogon scoparium					0.3													
Total Grasses	14.0	28.0	35.0	30.2	21.9	33.2	28.4	44.2	38.6	39.7	28.5	24.5	45.5	20.1	29.0	27.5	18.9	21.5

Table 6. Continued.

	Pasture Number																	
	1-4	1-6	2-1	2-2	2-3	2-6	3-1	3-2	3-5	3-6	1-2	2-4	2-5	3-4	1-1	1-3	1-5	3-3
Forbs																		
Croton pottsii						Tr								Tr	Tr	Tr		
Evax verma															Tr	Tr		
Conyza coulteri															Tr	0.3		
Aster spp.	Tr																	
Lesquerella fendleri		0.3			0.3													
Sphaeralcea coccinea		Tr		0.3														
Sphaeralcea angustifolia				Tr														
Astragalus mollissimus					1.0													
Dysodia pentachaeta														0.3				
Portulacca spp.														0.3				
Total Forbs	Tr	0.3	0.0	0.3	1.3	Tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	Tr	0.3	0.0	0.0
Shrubs																		
Gutierrezia sarothrae	2.0	1.0	3.0	2.8	5.3	3.8	3.0	Tr	0.6	0.8	0.5	Tr		0.3	1.0	0.3		1.3
Dalea formosa									Tr	Tr	Tr	Tr	0.5	Tr	Tr	Tr		
Nolina microcarpa			Tr	0.3	1.0	Tr	Tr				Tr			0.3	0.3	0.5		
Opuntia acanthocarpa					Tr						Tr	Tr						
Fallugia paradoxa											Tr							Tr
Acacia greggii				0.3										0.3	0.3			
Yucca glauca					0.3						Tr							
Opuntia engelmannii													Tr		Tr	Tr		
Eurotia lanata		Tr							Tr	Tr								
Yucca elata					Tr				Tr	Tr								
Parthenium incanum														0.3				
Krameria lanceolata																		Tr
Rhus aromatica														0.3				
Artemisia frigida									Tr	Tr								
Total Shrubs	2.0	1.0	3.0	3.4	6.6	3.8	3.0	Tr	0.6	0.8	0.5	Tr	0.5	1.2	1.6	0.8	0.0	1.3
OVERALL TOTAL	16.0	29.3	38.0	33.9	29.8	37.0	31.4	44.2	39.2	40.6	29.0	24.5	46.0	21.8	30.6	28.6	18.9	22.8

The pastures were divided into 4 groups based on vegetational similarity, topography, and elevational position (Table 7). The number of species in each group of pastures varied from 44 to 64 during the initial sampling. The lowland sites apparently were more diverse than those in the foothills. Frequency was determined from the 0.25 m^2 quadrats used for standing crop determinations. Again, several species were abundant in all areas: blue grama, sand dropseed, mat muhly, three awns, and broom snakeweed (Table 8). Tobosa was confined mostly to the lowland pastures while galleta (*Hilaria jamesii*), and New Mexico feathergrass (*Stipa neomexicana*) were most abundant on the upland pastures. There seemed to be no discernable pattern from north to south.

Diet Analysis

The diet of pronghorns was dominated by forbs (66-76% average relative frequency) throughout all pastures, seasons, and years (Table 9). Most of the values for individual pastures ranged from 60-80%, although extremes of 40-92% were observed.

Table 7. Pasture grouping, sample sizes and numbers of species sampled during 1979-80 inventory.

Geographical Region	Pastures Included	Number Quadrats	Number Species
South Hills	1-2, 2-4, 2-5, 3-4 S.P. Johnson	140	51
South Plains	1-1, 1-3, 3-3, Gist	290	64
North Hills	1-5, 2-1, 2-2, 2-6, 3-1, Circle F	210	44
North Plains	1-4, 1-6, 3-6, 3-2, 3-5, 2-3	170	60

Table 8. Frequency (%) of species from different geographic areas in the West Roswell area, 1979-80.

Species	South Hills	South Plains	North Hills	North Plains
Grasses				
Bouteloua gracilis	23	14	78	48
Bouteloua curtipendula	9	3	17	6
Bouteloua hirsuta	6	2	12	5
Bouteloua eriopoda	11	17	16	26
Scleropogon brevifolius	9	42	1	13
Sporobolus cryptandrus	17	10	26	27
Sporobolus giganteus	0	0	0	5
Muhlenbergia repens	9	1	8	5
Muhlenbergia richardsonis	12	8	24	8
Muhlenbergia torreyi	1	8	1	17
Muhlenbergia porteri	9	26	2	11

Muhlenbergia montana	0	0	5	0
Hilaria mutica	26	37	0	7
Hilaria jamesii	0	2	24	8
Erioneuron puchellum	17	13	0	14
Erioneuron pilosum	46	37	8	32
Tridens muticus	9	8	0	5
Aristida spp	35	12	29	33
Panicum virgatum	14	5	1	3
Lycurus phleoides	14	0	14	13
Stipa neomexicana	0	0	18	5
Forbs				
Croton corymbulosus	8	0	1	0
Croton mono	1	0	0	5
Conyza coulteri	0	5	0	0
Lesquerella fendleri	0	1	41	0
Chamaesarcha conoides	1	0	0	6
Evax verna	0	17	0	0
Aster spp.	0	0	12	1
Shrubs				
Gutierrezia sarothrae	39	48	61	70
Acacia gregii	12	7	0	7
Dalea formosa	7	0	0	2
Nolina microcarpa	11	0	2	9
Opuntia acanthocarpa	17	8	1	5
Opuntia engelmannii	4	7	1	4
Eurotia lanata	0	0	6	0

No individual pastures consistently stood out as having relatively high or low values. The relative frequency of grass in the seasonal diet of pronghorns averaged approximately 1-5% with a range of 0-19% for individual pasture-season combinations (Table 9). Browse use by pronghorns was intermediate to forbs and grass. Average relative frequency values indicated their diet was comprised of approximately 20% browse in the summer and fall seasons and approximately 30% in the winter and spring seasons (Table 9).

Cattle diets were dominated by grasses in all pastures during all sample periods. The average dietary composition of grass ranged from approximately 67-77%, and all values for individual pastures were within 20% of these averages (Table 10). There was an apparent inverse relationship between the relative amounts of forbs and browse consumed by cattle. The seasons of highest forb use, summer (19%) and fall (28%), corresponded with the lowest use of browse, approximately 3-5% (Table 9). Conversely, browse use by cattle was highest (15%) and forb use lowest (13-15%) in winter and spring.

The diet of sheep was comprised of approximately equal amounts of grass and forbs (39-45%) in winter, spring, and summer, although in fall the average dietary composition of grass declined to 33% and that of forbs increased to 52% (Table 9). The percent composition of browse in the diet of sheep ranged from approximately 2-38% for individual pastures in certain seasons, but the average values across all pastures ranged from

Table 9. Average (and range) of relative frequencies (%) of grasses, forbs and browse in the seasonal diets of cattle (C), pronghorns (P) and sheep (S) on 15 study areas in east-central New Mexico, as determined by fecal analysis, from fall 1979 through fall 1982.

Forage	Fall			Winter			Spring			Summer		
	C	P	S	C	P	S	C	P	S	C	P	S
Grass	67.2 (53-83)	5.3 (1-20)	33.2 (18-55)	72.6 (57-97)	1.4 (0-9)	38.9 (23-61)	69.9 (47-89)	3.4 (1-10)	43.7 (32-54)	77.5 (62-93)	2.6 (0-6)	41.2 (27-52)
Forbs	28.3 (12-44)	73.8 (67-86)	52.2 (36-64)	12.9 (3-33)	65.8 (40-92)	40.7 (22-59)	14.7 (4-47)	65.8 (45-85)	42.6 (28-62)	18.9 (6-34)	75.8 (47-91)	45.9 (32-64)
Browse	3.4 (1-9)	20.9 (9-31)	14.5 (6-24)	14.5 (4-27)	32.8 (3-58)	20.1 (2-38)	15.4 (2-38)	29.8 (4-53)	13.7 (2-32)	4.6 (1-14)	21.6 (7-50)	12.8 (6-19)

only about 13-15% for spring, summer, and fall and 20% for winter (Table 9).

Selectivity Indices further attested to the importance of forbs, and to a lesser extent browse, in the diet of pronghorns in this area (Table 10). Some species, such as Artemisia ludoviciana, Croton spp., Sphaeralcea coccinea, S. angustifolia, and Opuntia spp., had relatively high indices in all seasons. Other species represented by relatively high index values in at least 2 seasons were: Verbena spp., Eriogonum spp., Dalea formosa, Gutierrezia sarothrae, Euphorbia spp., Abutilon incanum, Rhus microphylla, Sida spp., and Krameria lanceolata. Ambrosia psilostachya, which had the highest overall ranking, was represented by an extremely high average selectivity value in the summer seasons and relatively low values in the other seasons. Similar seasonally disproportionate use was indicated by the relatively high indices in the spring season for Astragalus spp., Marrubium vulgare, Leucelene spp., Eurotia lanata, and Lithospermum spp. and in the winter season for Zinnia grandiflora, Conyza coulteri, and Erodium spp.

Some plants had relatively high relative frequency values, at least in certain seasons, for the diet of cattle, pronghorns, and sheep, (Appendix II). Although the values were higher for

Table 10. Average Selectivity Indices (relative frequency in diet/relative biomass available on respective study pastures) for dietary items of pronghorns, as determined from winter 1980 through fall 1982.

Species	Fall	Winter	Spring	Summer	Overall Rank
Ambrosia psilostachya	475	300	399	18,165	1
Artemisia ludoviciana	1,736	1,476	1,340	7,555	2
Croton spp.	1,841	1,570	6,222	2,417	3
Sphaeralcea coccinea	4,800	574	1,464	2,830	4
Opuntia spp.	1,758	1,835	2,950	1,291	5
Eriogonum spp.	2,128	531	32	4,430	6
Dalea formosa	2,130	27	29	3,352	7
Solanum elaegnifolium	261	219	277	4,661	8
Sphaeralcea angustifolia	1,745	1,167	1,138	1,035	9
Verbena spp.	1,021	31	1,173	2,267	10
Gutierrezia sarothrae	57	1,928	2,664	264	11
Euphorbia spp.	999	215	426	2,894	12
Abutilon incanum	3,076	20	234	924	13
Rhus microphylla	293	919	1,472	1,097	14
Sida spp.	959	0	0	2,719	15
Astragalus spp.	343	31	2,103	337	16
Krameria lanceolata	1,215	84	955	503	17
Ratibida columnaris	857	179	1,407	313	18
Quercus undulata	270	70	780	1,354	19
Marrubium vulgare	753	13	1,294	284	20
Lesquerella fendleri	305	370	1,535	35	21
Leucelene spp.	292	166	1,173	182	22

Zinnia grandiflora	1,302	80	32	825	23
Polygala spp.	811	286	565	438	24
Eurotia lanata	154	27	1,758	60	25
Plantago patagonica	491	89	432	590	26
Artemisia filifolia	889	0	53	660	27
Dalea jamesii	483	27	140	1,043	28
Conyza coulteri	1,227	14	277	75	29
Evax verna	719	112	212	75	30
Lithospermum spp.	295	13	1,231	122	31
Erodium spp.	1,162	0	112	218	32
Calylophus serrulatus	402	0	188	438	33
Heterotheca spp.	225	57	611	131	34

cattle and sheep, grasses in this category were *Bouteloua gracilis*, *Sporobolus* spp., and *Stipa* spp. Five forb species (*Croton* spp., *Abutilon incanum*, *Sphaeralcea coccinea*, *S. angustifolia*, and *Verbena* spp.) apparently were eaten in approximately equal amounts by the 3 herbivores. Other forbs in this category, although with disproportionate use by the 3 herbivores, were *Ambrosia psilostachya*, *Lesquerella fendleri*, and *Sida* spp. Of the browse, only *Opuntia* spp. was represented with consistently high relative frequencies for these animals.

Grasses utilized in relatively large amounts by cattle and sheep but not pronghorns were *Bouteloua curtipendula*, *B. eriopoda*, *Erioneuron pilosum*, *Lycurus phleoides*, *Muhlenbergia* spp., *Aristida* spp., and *Setaria leucopila* (Appendix II). No forb or browse species were consistently utilized by either class of livestock in greater amounts than pronghorns. Pronghorns and sheep utilized *Artemisia ludoviciana*, *Cassia* spp., *Berlandiera lyrata*, *Calylophus serrulatus*, *Conyza coulteri*, *Eriogonum* spp., *Lesquerella* spp., *Brickellia brachyphylla*, *Dalea formosa*, *Rhus aromatica*, and *R. microphylla* disproportionately more than cattle (Appendix II)..

The only plants consistently utilized by cattle disproportionately more than by the other 2 herbivores were *Andropogon* spp. and *Sorghastrum avenaceum*. Similarly, *Eurotia lanata* was the only plant consistently represented by higher relative frequency values for sheep than for cattle or pronghorns. In contrast, pronghorns consistently utilized *Euphorbia* spp., *Evax verna*, *Galium microphyllum*, *Linum rigidum*, *Melampodium leucanthum*, *Plantago patagonica*, *Polygala* spp., *Salvia* spp., *Juniperus monosperma*, and *Prosopis glandulosa* disproportionately more than did cattle or sheep (Appendix II).

The results of the Similarity Index comparisons suggested that the diets of cattle and pronghorns are more dissimilar than are those of either pronghorns or cattle compared to sheep (Table 11). The average indices for the cattle - pronghorn comparison ranged from approximately 13 to 17 during winter, spring and summer, and increased to 20.1 in the fall. The pronghorn-sheep comparison followed a similar pattern with the average value in the fall being higher than that for the other seasons. In contrast, the Similarity Index for the cattle-sheep comparison was lower in the fall than in the other 3 seasons.

Table 11. Average (and range) of Similarity Indices for the comparative diets of cattle, pronghorns and sheep on 15 study pastures in east-central New Mexico from fall 1979 through fall 1982.

	Animal comparison		
Season	Cattle-pronghorn	Pronghorn-sheep	Cattle-sheep
Fall	20.1	44.1	42.4
	(9-34)	(26-60)	(26-51)
Winter	13.9	38.2	43.9
	(3-27)	(23-60)	(24-68)
Spring	17.5	38.5	47.0
	(7-33)	(24-61)	(41-54)
Summer	13.0	35.1	51.6
	(6-27)	(24-43)	(28-98)

Fawn Production and Survival

Maximum fawn production per female and seasonal survival varied among pastures and among years during the study (Appendix III). Yearling pronghorns could be distinguished from adults only during the summer 1980 through spring 1981. At this time all collared animals were adults, since they had been brought to the study as adults or yearlings in spring 1979, and all uncollared animals not fawns were yearlings and survivors from the first fawn crop of the study, born in 1979. Beginning with the summer of 1981, uncollared animals distinguishable from fawns included both yearlings and older animals. For the time that yearlings were identifiable, the survival rates of yearlings and adults of the same sex were almost identical, so yearlings and adults (both collared and uncollared) were lumped into the same age category for analyzing and reporting pronghorn population data. During the study, the pattern of fawn survival was most similar to that of older animals in the fall and most different in the spring.

Viability Index

One of the objectives of this study was the evaluation of the suitability of the study pastures for stocking pronghorns. To apply these results to other pastures in New Mexico, some index of suitability is needed. Those conditions favoring increasing pronghorn populations were of interest, and increasing populations depended on increasing the pool of breeding females, so the change in the number of potential mothers was chosen as an appropriate index of suitability of the pasture habitats for pronghorns. The selected index for this study was the ratio of potential breeding females at the end of the study to initially stocked breeding females, and is called the Viability Index.

Clearly the number of actual and potential recruits to the female breeding population varies throughout the year, being greatest in the early summer when fawn numbers are highest, and least in the spring after annual mortality but before new births have occurred. Females are considered as recruited into the breeding population when they are mature enough to conceive, namely in the fall of their yearling year. The number of fawns that are potential recruits depends on the probability of their survival through the fall of their yearling year, and the fraction of survivors that is female. The fall season was chosen as the time for calculating the Viability Index for the study since the last pronghorn observations were made in the fall. All of the surviving collared and uncollared females other than fawns at the end of the study can be considered as recruited into the pool of breeding females, and thus contribute to the totals of actual and potential mothers. The number of female fawns expected to become breeding females then remains to be determined.

The number of recruited mothers expected from the fall fawns depends on the probability of their survival until the following fall and on the fraction of females among the survivors. For the study pastures, over the 3 complete years of the study, the average survival rate for fawns from September through the following June was 0.65, and of those fawns that survived to be yearlings, 60% were female. For the 4 summer seasons of the study, the survival rate over the summer for yearling and adult females averaged 0.90. Thus, the expected number of females eventually recruited into the breeding population from fall fawns can be calculated as (fall fawns) x (0.65) x (0.60) x (0.90), or (fall fawns) x (0.35).

The Viability Indices for the antelope herds in the study pastures was calculated as follows:

$$\text{Viability Index} = \frac{(\text{fall \# fawns} \times .35) + (\text{Fall \# adult + yrlng females})}{(\text{initial number of stocked females})}$$

The number of stocked females, the final number of females and fawns, and the calculated Viability Index shows that 5 study pastures were suitable for pronghorns (Table 12). A Viability Index of less than 1 indicates a declining population, and an index of 1 indicates no population growth after 3 years. Those pastures with indices of 1.3 and up have shown increasing pronghorn populations.

Year-to-Year Differences for All Pastures

The study area as a whole experienced both favorable and unfavorable environmental conditions during the time that the pronghorn stocking experiment was in progress. The variety of environmental conditions, closely tied to rainfall patterns, was fortunate from the point of view of the study, since it enabled us to distinguish the influence of weather from that of intrinsic pasture characteristics such as vegetational characteristics, ruggedness, and size. Data for rainfall, forb standing crop, fawn production and survival, and adult survival averaged over all pastures at each season for the duration of the study show these variations (Tables 13 through 16).

There were 2 dry periods during the course of the study, the first from the fall 1979 through the summer of 1980 (33% of the wettest corresponding period during the study), and the

Table 12. Viability Indices for pronghorns on the 18 study pastures in east-central New Mexico, 1979-82.

Pasture number	Numbers Stocked (females)	Numbers at end of study		Viability Index
		females	fawns	
1-1	9	17	14	2.43
1-2	7	5	4	0.91
1-3	6	11	6	2.18
1-4	5	0	0	0.00
1-5	6	11	3	2.01
1-6	6	7	0	1.17
2-1	14	6	0	0.43
2-2	12	7	1	0.61
2-3	11	7	5	0.80
2-4	12	0	0	0.00
2-5	11	0	0	0.00
2-6	13	22	9	1.93
3-1	17	0	0	0.00
3-2	19	22	7	1.29
3-3	17	31	22	2.28
3-4	19	0	0	0.00
3-5	20	10	5	0.59
3-6	17	17	2	1.04

Table 13. Average rainfall in inches (cm) for 18 study pastures, 1979-82. a

Year	March - May	June - July	August	September - November
1979	2.69	1.99	2.49	0.88
	(6.83)	(5.05)	(6.32)	(2.24)
1980	1.17	1.06	2.72	2.66
	(2.97)	(2.69)	(6.91)	(6.76)
1981	2.08	4.69	4.56	1.61
	(5.28)	(11.91)	(11.58)	(4.09)
1982	1.10	2.33	2.78	3.68
	(2.79)	(5.92)	(7.06)	(9.35)

a Data not collected for December through February.

Table 14. Average forb standing crop in lbs./acre(kg/ha) by season for 18 study pastures, 1979-82.

Dates	Spring	Summer	Fall	Winter
12/79-2/80	--	--	--	8.9
				(10.0)
3/80-2/81	10.9	26.1	100.5	26.1
	(12.2)	(29.2)	(112.6)	(29.2)
3/81-2/82	34.3	59.9	77.1	15.9
	(38.4)	(67.1)	(86.4)	(17.8)
3/82-9/82	21.7	31.8	65.1	--
	(24.3)	(35.6)	(72.9)	

Table 15. Annual fawn production and seasonal fawn survival averaged for 18 study pastures, 1979-82.

Dates	Max fawns/ female	Fawn survival rate			
		Summer	Fall	Winter	Spring
6/79-5/80	0.97	0.94	0.92	0.86	0.47
6/80-5/81	0.50	0.72	0.70	0.86	0.89
6/81-5/82	0.84	0.89	0.77	0.91	0.80
6/82-9/82	0.47	1.00	--	--	--

Table 16. Seasonal survival for yearlings and adults combined, for females and males, averaged for 18 study pastures, 1979-82.

Dates	Summer		Fall		Winter		Spring	
	f	m	f	m	f	m	f	m
6/79-5/80	.96	.97	.93	1.00	.91	.88	.95	.86
6/80-5/81	.89	.86	.79	.85	.94	1.00	.94	.98
6/81-5/82	.93	.92	.88	.91	.92	.99	.81	.90
6/82-9/82	.81	.79	--	--	--	--	--	--

second from the fall of 1981 through the spring of 1982 (57% of the wettest corresponding period during the study). In between, the fall of 1980 was rather wet throughout the study area. Temperatures were well correlated with rainfall, with cooler temperatures occuring during wet seasons.

The general pattern of forb abundance is related to rainfall patterns, with forb standing crop during relatively dry winter and spring seasons being approximately 50% of forb standing crop during wet winter and spring seasons. The highest average summer forb standing crop occurred in 1981 which was the wettest summer. Fall forbs in 1981 were lower than that in 1980, reflecting fall but not summer rainfall. This is an indication of the importance of the timing of rainfall as well as the annual total.

DISCUSSION

Task I: Livestock/Pronghorn Fencing

Fencing has long been a standard livestock management practice beginning with the initial introduction of cattle and sheep on western ranges. The use of fences to divide rangelands into manageable areas of land may achieve important livestock management objectives. May (1968) summarized a number of key advantages resulting from the fencing of western ranges. These include more uniform distribution of animals, protection of overgrazed or treated areas, segregation of livestock classes or livestock types, increase forage production, and reduction in handling of livestock. Fences have the important disadvantage of restricting movement of some wild ungulate species.

Wildlife managers recognize fencing as a major management problem associated with pronghorns. This is because fences can restrict pronghorn movements to obtain food and/or water, or to escape harsh weather (Yoakum 1978). Russell (1964) included wire fences as an important factor contributing to reductions in pronghorn numbers throughout the west. Newman (1966) found that Wyoming pronghorn numbers decreased substantially when movements of animals were restricted by livestock fences. It was shown that fences caused a restriction of pronghorn movements to areas where forage was more available. Pronghorns which were not allowed free movement over a large area were in poor condition and showed signs of starvation. Other studies concerned with the subject have shown similar findings (Russell 1951, Mapston 1972, B.L.M. 1975).

A variety of fence types are presently employed on western ranges depending upon livestock type and class. Sheep operators commonly prefer net wire fencing while operations involving cattle may require the use of barbed wire structures for restrictive purposes. Mapston (1972) suggested that both net wire and barbed wire can cause serious problems for pronghorns by restricting movement and feed selection. Bear (1969) found that sheep fences, 1.12 m (44 in) in vertical height, will restrict nearly all pronghorns while net wire structures 81.3 cm (32 in) high will restrict only fawns. It was also found that on cattle ranges, where it is common practice to use barbed wire fences, pronghorns were restricted to a lesser extent but often injuries occurred during passage that lead to permanent crippling or death

(Spillett 1964). In all cases it appears that standard livestock fences have some negative effect upon pronghorn mobility.

The inability of pronghorns to cross these structures cannot be explained entirely. Findings by Rouse (1954) and Spillett (1965) indicated that pronghorns have inherent abilities to jump certain structures. Spillett (1965) found certain pronghorns could negotiate 1.9- to 2.5-m (6 to 8 ft) high fences but generally a 1.19-m (47 in) vertical structure would prevent pronghorn passage. O'Conner (1961) recorded pronghorn leaps of 4.3 to 8.2 m (14 to 27 ft) horizontally which indicated remarkable leaping ability. Although pronghorns have the potential to leap nearly any fence structure presently used on the range, in many cases, they shy away from livestock fences or fail to acquire the familiarity with certain structures which will enable them to negotiate passage.

After reviewing several studies concerning fencing and pronghorns, Yoakum (1978) suggested measures be taken to reduce pronghorn mortality from fencing which include minimizing construction of net wire fences, using barbed wire fences with a smooth bottom strand at least 41 cm (16 in) above the ground and no stays between posts, providing special pass structures such as lay-down panels or pronghorn jumps along heavily traveled pathways and/or migration routes, and fencing areas as large as possible.

The development of a structure which will ultimately solve the pronghorn/fence problem has become an important objective of researchers and still no definite answer has been found. Many field observations concerning pronghorn passage through pre-existing or experimental structures are available. Spillett et al. (1967) concluded from field observations and experimental results that maximum heights for any vertical structure which will not restrict pronghorns should be no greater than 81.3 cm (32 in). Spillett et al. (1967) recommended that in cases where vertical structures were required for livestock restriction only smooth wire structures be used in order to reduce possible injuries to pronghorns.

Several studies testing pronghorn pass structures have shown pronghorn passage was most frequent on horizontal modified cattle guards (Spillett 1965, Bear 1969, Pate 1969, Mapston 1970). Field observations of pronghorns using cattle guards as a means of passage are numerous (Spillet 1964, Spillett 1965, Spillett and Zobell 1967, Woody et al. 1967, Zobell 1968a, Zobell 1968b, Pate 1969). These observations indicated that pronghorns commonly leap 1.8 to 2.1 m (6 to 7 ft) cattle guards. Mapston (1968) and Pate (1969) found that these horizontal devices worked effectively even to the extent of allowing passage of 1-month-old fawns. Studies by Newman (1966), Mapston (1968), and Bear (1969) have verified the movement of pronghorns into and out of pastures with perimeter fences of net wire when experimental horizontal passes were present. These studies indicated that problems associated with pronghorn restriction by livestock fences can be solved by the use of low, vertical passes or preferably horizontal cattleguard devices.

Since research has shown that certain structures do allow passage by pronghorns, the effectiveness of these structures in restricting livestock movement becomes an important concern. A limited number of studies have dealt with this matter (Rouse 1954, Cole 1956, Spillett et al. 1967), but results were not conclusive. Bear (1969) found that although several vertical structures adequately restricted livestock, these structures were different than those recommended for pronghorn passage. Mapston and Zobell (1970) concluded that a 1.8 m (6 ft) horizontal grill would serve to restrict most livestock movement without restricting pronghorns. However, sheep restriction was not always effective.

Fence Modifications

Fence modifications placed in existing net wire fences on the James Gist, Circle F and S. P. Johnson ranches showed varying levels of usage by pronghorns. Type of pass structure, location in regard to terrain and fence corners, and numbers of pronghorns present to use the passes no doubt influenced the amount of use for any given pass structure.

Passes #2 and 5 on the James Gist ranch were reduced to 3.7 m (12 ft) on 6 November 1980 and pass #2 was replaced with the modified pronghorn grill (Fig. 7) on 12 December 1980. Subsequently, pronghorn crossings remained high during 1981 and 1982 for pass #5 while crossings at the pronghorn guard (formerly pass #2) declined by 71% (Table 1) when compared to the number of crossings/month for 1979 and 1980. These observations indicate that a narrow pass within a net wire fence will continue to be used by pronghorns once they have located the pass and become

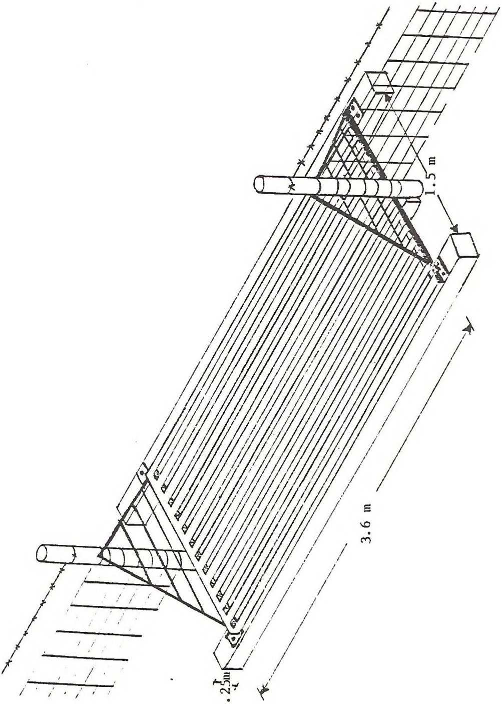


Figure 7. Characteristics of the modified horizontal pronghorn grill.

accustomed to crossing at that place. Apparently, the modified horizontal pronghorn grill with its extra structures caused pronghorns to become wary of crossing the net wire at a place that previously was suitable. A longer period of testing would indicate whether the pronghorns on the Gist Ranch would accept the horizontal pronghorn grill or avoid crossing this structure.

It was apparent the Paul's Pass (Russell 1964) on the S. P. Johnson Ranch was not a suitable structure to permit movement by pronghorns on this ranch. Certain passes on the James Gist and Circle F ranches received little or no use during some years. These passes apparently were not placed strategically to allow for high exposure to sufficient numbers of pronghorns. As a result pronghorns seldom approached the fences at these locations and, therefore, never became aware of these potential crossings.

The numbers of pronghorns within an area obviously influences the amount of use a pass structure receives, assuming the structure is located at a suitable site. Pronghorns in the vicinity of and on the James Gist Ranch showed a greater tendency to move between pastures than did those on the Circle F Ranch. These animals were not completely restricted by net wire fences as the ranches to the east of the Gist Ranch had barbed wire fences. Possibly, the pronghorns in this area were more mobile because they had learned that large areas were available to them in the other pastures of the Gist Ranch as well as on the neighboring ranches to the east.

Off-site Fence Tests

Analysis of data indicated that no panel structure ultimately solved the problem of livestock restriction. Passes which proved successful in restricting cattle movement were those which were constructed of barbed wire. In cases where smooth wire was included as a structural material, as in the net wire variation, cattle were able to press against the fence and merely push down the panel. The 81.3 cm (32 in) net fence did not restrict cattle because of its height. Cattle merely stepped over the structure or pushed it down. This also was true for the net wire variation even though it had 1 barbed wire strand above the net wire.

Sheep and calves were able to crawl through several of the fence types. All wire strand fences were inferior to the 81.3 cm (32 in) net wire fence when the trial involved the use of smaller livestock. Barbed wire strands had little effect on discouraging these animals from crossing. Lambs, in particular, were able to pass beneath wire strands on all fences except the 81.3-cm (32 in) net wire.

Although sheep and calves did not show the ability to jump over fence structures, as did adult cattle, they were capable of jumping the pronghorn guard. Typically, crossings of this device were accomplished by an angular jump of approximately 76 cm (30 in) from the guard corner. This problem could be partially solved by the addition of wings to each end of the pronghorn guard. Crossings of the pronghorn guard by lambs also were made by walking down a center steel support strip approximately 15 cm

(6 in) in width. The removal or narrowing of this support may alleviate this problem.

The ability of different animal classes and animal types to cross panel structures complicates development of an effective fence which will restrain livestock but allow passage of pronghorns. The ability of cattle to jump low fences (net wire) and break through smooth strand fences (net wire variation) coupled with the ability of sheep to jump or crawl through these structures increases design problems. Pass structures that will restrict both cattle and sheep may have a similar effect upon pronghorns.

Selection of a pass structure depends upon the type and class of livestock utilizing an area. In situations where cattle are the primary livestock, results indicated that the pronghorn guard or the 4- strand barbed wire standard should be utilized. Although both pass types may serve to restrict cattle, observations indicated that the pronghorn guard is more readily utilized by pronghorns (Hendrickson 1967, Kerr 1968). For this reason the pronghorn guard may serve to restrict cattle effectively without inhibiting pronghorn passage. The pronghorn guard is recommended for all pastures where adult cattle are found including areas used for breeding purposes since the pronghorn guard restricts bull movement. Calving pastures may require the use of the 4- strand barbed wire standard or the net wire variation to restrict calf movements.

In pastures where sheep are the primary livestock, results indicated that the horizontal pronghorn grill should be utilized.

Small lambs were able to crawl under the 4-strand barbed wire standard. The 32-inch (81.3 cm) net wire would probably contain ewes and lambs, but not rams, while allowing pronghorns to jump into adjoining pastures. Rams probably would have to be contained in a net wire pasture with 2 or more strands of barbed wire above the net wire. This pasture probably would not be accessible to pronghorns.

Task II: Fawn Production and Survival

Several authors have documented the effects of predation upon production and survival of pronghorn fawns and upon increases or decreases of pronghorn herds (Einarsen 1948, Buechner 1950, Arrington and Edwards 1951, Udy 1953, Hailey 1979, and Neff 1979). These authors report that significant impacts can be made upon fawn survival by coyotes and golden eagles, particularly when herds are relatively small in number. Coyotes should not have been responsible for many fawn losses in the study area as intensive predator control was carried out by U.S. Fish and Wildlife Service, Animal Damage Control personnel throughout the area during all years of the study. No attempt was made to estimate pronghorn losses to golden eagles although eagles were common in the area. One attack by a golden eagle on a yearling pronghorn was observed during a spring aerial survey in 1981.

Buechner (1950) and Hailey (1966) both reported on the effects of net wire fencing restricting movements of pronghorns to areas containing more favorable forage conditions in West Texas. These authors stated that restricted movement, particularly during periods of limited forage, would cause pronghorn herds to either decline in numbers of die-off completely if poor forage conditions prevailed for several weeks. Drought, deep snow and over-grazing by livestock could contribute to the paucity of forage for pronghorns.

The 2 lowest average values for maximum observed fawn production occurred in 1980 and 1982 following the 2 dry winters. Fawn production in 1981 was almost double that in either 1980 or 1982, and followed the highest rainfall for the September through March periods. Interestingly, the largest observed value of fawns per female was the first year of the study, from stocked females pregnant when captured away from the study area. This may indicate that capturing, transporting and releasing operations were not detrimental to pregnant females.

Average fawn survival was reduced during the dry periods of the study. Survival of older animals also was slightly depressed during these same times, but fawns were more affected by poor conditions than adults. It should be noted that mortality of very young fawns was not observed in this study because the first overflight after fawning was in June. Thus, it is possible that actual fawn production was less variable than indicated by our data, and that differences in observed maximum fawns per female were due to increased mortality of newborn fawns during the 2 driest springs. However, young fawns were observed during June and July in all years of the study.

No single season was consistently critical for the survival of any population category. Instead, both plant production and pronghorn population trends in general were tied to variations in the amount and timing of rainfall for the study area as a whole.

Viability Index

Pronghorn population trends across pastures over time were related to rainfall, as were differences among pastures at any one time. That result poses something of a problem with respect to selecting pastures for pronghorn stocking, since advice to choose pastures that will have good rainfall would be accurate but not easily accomplished.. So, analyses were done using the Viability Index for each pasture as the dependent variable with a selection of independent variables that could reasonably be known before a pasture is stocked, such as pasture characteristics that remain constant over time, or other factors subject to planning, such as stocking rates.

The Viability Index indicates how pronghorn herds in the study pastures had fared after a series of favorable and unfavorable years, so it is a useful index to the suitability of the study pastures for pronghorns. Before the study began, half of the pastures were considered to be good habitat, and half poor. Using a dummy variate of 1 for designated as good (group A) and 0 for those considered to be poor before the study started (group B), the correlation of assumed suitability grouping with the viability indices at the end of the study was 0.27, indicating that there was still something to be learned about suitable habitat for pronghorns.

The independent variables considered in regressions with viability index for this first part of the data analyses for the study included such pasture characteristics as size, ruggedness index, and latitude. Additional factors from vegetation surveys were considered, namely general vegetation type, range site types, percent of climax species, basal cover of grasses, forbs, and shrubs, and estimated annual production under average conditions from SCS and the SVIM surveys. Of these factors, the ruggedness index was the most useful, with a correlation with Viability Index of -0.58, indicating that more rugged terrain is less suitable. All of the pastures with resource areas classified as Southern Desert had Viability Indices of at least 2.0, but also had low ruggedness indices. No relationship between viability and range site types was apparent. None of the other parameters from early vegetation surveys turned out to be useful predictors of viability.

There was 1 parameter measured in the later vegetation studies that was a useful predictor of viability in combination with ruggedness, namely the average number of forb species present during the fall. The number of forb species was greater in the fall than in other seasons, as was the forb standing crop. The number of fall forbs was closely associated with latitude for our study pastures, with more southerly pastures having greater forb diversity. The number of fall forbs is a parameter that could reasonably be determined before selecting pastures for future antelope stocking through a vegetation survey. The maximum potential number of forbs would follow appreciable late summer rains. A regression of Viability Index against ruggedness, pasture size, and fall number of forbs accounted for

63.6% of the variation observed in viability.

Anticipated stocking rates for cattle and sheep is another factor that could reasonably be estimated before deciding whether to stock pronghorn in a given pasture. Throughout our study, increasing antelope herds were not found to be compatible with sheep stocking rates greater than 10 animal units or 50 sheep per section. Sheep and cattle stocking rates for each season, averaged over the study, were all considered as variables for improving the regression of viability against ruggedness, size, and forb diversity in pastures. The addition into the model of average sheep densities in the fall increased the explained variation to 75.7%, resulting in the best regression found for evaluating pasture suitability for pronghorn stocking from *a priori* variables.

In the regression (Table 17), the variable for fall number of forbs enters with a positive coefficient, and the other variables for ruggedness index, fall sheep density, and pasture size, all have negative coefficients. In our study pastures, sheep densities tended to be higher on the more rugged pastures, compounding the unsuitability of rugged terrain for pronghorns. Large pasture size appears to be a disadvantage as well, but only after forb diversity, livestock, and ruggedness are taken into consideration. Larger pastures tended to have greater forb diversity, if only because they encompass a greater variety of range sites, and the increased diversity tends to offset the disadvantage of size *per se*.

Table 17. Results of the best regression of Viability Index for pronghorns against *a priori* variables for 18 study pastures.

Dependent variable: Viability index	
Independent variable	Coefficient
Ruggedness index	-0.00562
Pasture size in sections	-0.06751
Ave. fall number of forb species	0.10642
Ave. fall sheep, animal units/section	-0.05931
Intercept	1.08170
Regression	
Degrees of freedom	4
Sum of squares	9.66675
Mean	2.41668
Error	
Degrees of freedom	13
Sum of squares	3.09569
Mean	0.23813
Standard error of estimate	0.43986
F-value	10.14
Multiple R squared	75.7

Pasture size was a variable of great interest when this study was designed. The coefficient of pasture size (Table 17) indicates a slight disadvantage with increasing pasture size. However, the interpretation of the effect of pasture size is not straightforward for this study, since the medium-sized pastures were considerably more rugged on average than either the small or large pastures, and had lower average numbers of fall forbs and lower winter forb production than the other 2 size groups (Table 18). Large pastures tend to have greater forb diversity, which enhances suitability for stocking with pronghorn.

As noted previously, rainfall patterns were closely related to success of pronghorn populations in the study pastures. Adding the total rainfall from August through November to the regression of viability against _a priori_ variables adds almost 10% to the percentage of variability explained by the regression. Table 19 shows the ranges and average values of the _a priori_ variates and fall rainfall for pastures grouped according to Viability Index (Table 19).

Table 18. Comparison of the pasture size-groups with respect to other selected parameters.

Variable	Average for pastures in size groups		
	Small	Medium	Large
Size (sections)	4.8	8.6	12.3
Ruggedness index	48.5	83.7	51.7
Fall number of forbs	12.2	9.2	14
Winter total forbs	21	11	17
in lbs/acre (kg/ha)	(23.5)	(12.3)	(19.0)

Table 19. Average values and ranges of selected parameters for 18 study pastures grouped according to suitability for pronghorns.

Average (range)	Pasture group		
	Herd increased	Very little change	Herd declined
Viability	2.02	0.98	0.20
Index	(1.29 - 2.43)	(0.80 - 1.17)	(0 - 0.61)
Size in	7.9	7.2	9.8
sections	(3.9 - 13.3)	(3.9 - 12)	(6 - 14.9)
Ruggedness	42.3	48.3	82.0
index	(28 - 65)	(31 - 80)	(38 - 131)
Fall forb	15.3	10.5	9.8
numbers	(10.3 - 20.3)	(8 -12)	(5.3 - 16)
Fall sheep	2.3	7.7	10.9
AU/section[a]	(0 - 7.6)	(3.4 - 9.4)	(3.4 - 24.2)
Fall rain	5.28	5.65	4.62
in inches	(3.99 - 6.73)	(4.67 - 6.68)	(1.78 - 6.20)
Spring total preferred			
Forbs	17.50	10.45	4.80
lbs/acre	(4.40 - 33.17)	(6.47 - 20.67)	(0.20 - 9.70)
kg/ha	(4.93 - 37.15)	(7.25 - 23.15)	(0.22 - 10.86)

[a] One animal Unit = 5 sheep.

Seasonal Differences Among Pastures

Vegetation and Physical Factors

Clear trends emerged from the first part of the analyses, namely consideration of the study data averaged over all pastures for each season, and averaged over all seasons for each pasture. The second part of the data analyses examined differences among pastures over the duration of the study, without any lumping or averaging of data points. Pronghorn production and survival were considered with respect to environmental factors associated with the observed changes in the study herds. The resulting picture was somewhat more complicated than the general trends.

The importance of rainfall patterns to pronghorn population trends has been indicated previously. The impact of rainfall is expressed through the relationship between rainfall and vegetation, or food availability for pronghorns. Analysis of vegetation data will concentrate on forbs, since fecal analysis studies clearly have shown the dominance of forbs in pronghorn diets. The particular forb species with the highest importance values from the fecal analysis are called preferred forbs. The preferred forb list can be separated into 2 groups, with the first group having the highest importance values and referred to as preferred forbs I. Total preferred forbs refers to both groups combined (Appendix IV).

The sampling design for the study allowed the analysis of several variables related to forbs for each season, including total forb standing crop, preferred forbs I, combined preferred forbs I and II standing crop, and number of forb species, a simple measure of diversity. Data on these parameters were available from each pasture in the study for each season during the study, beginning with the winter of 1979-80. Rainfall, especially in late summer and fall, was associated with higher total forbs, combined preferred forbs, and number of forb species. In addition to rainfall, ruggedness (negative coefficient, or lower plant standing crop for more rugged terrain), and latitude (higher plant standing crop toward the south) were consistently important variables in regressions with vegetation paramters as the dependent variable. Pasture size was usually a significant variable as well and generally entered with a positive coefficient. The tendency for larger pastures to have higher average plant standing crop may be related to the likelihood of greater diversity in the larger areas with an increased chance of a more productive site. Physical factors alone generally accounted for 25 - 55% of the variation observed in forb standing crop between pastures in each season.

In examining vegetation data from each pasture for each season, using observations from all years for that season, the various forb parameters did not vary in the same way. Standing crop of combined preferred forbs and total forbs were similar in the spring and summer, but less so in fall and winter. Ice cream forbs and combined preferred forbs were most similar in the fall and least similar in the spring. The numbers of forb species and total forb standing crop were unrelated in the fall, but similar in other seasons (Table 20). It is apparent that the forb parameters provide different information at different times during the year, and that no single forb parameter consistently represents any of the others throughout the year.

Table 20. Correlation coefficients among forb parameters by season for 18 study pastures.

TF: total standing crop of forbs

NF: number of forb species

PF1: standing crop of preferred forbs I

PF1&2: standing crop of combined preferred forbs I & II

SUMMER

	TF	PF1	PF1&2	NF
TF	1			
PF1	.60	1		
PF1&2	.93	.73	1	
NF	.77	.58	.71	1

FALL

	TF	PF1	PF1&2	NF
TF	1			
PF1	.60	1		
PF1&2	.74	.88	1	
NF	.08	-.04	-.07	1

WINTER

	TF	PF1	PF1&2	NF
TF	1			
PF1	.48	1		
PF1&2	.86	.64	1	
NF	.66	.29	.55	1

SPRING

	TF	PF1	PF1&2	NF
TF	1			
PF1	.44	1		
PF1&2	.92	.39	1	
NF	.68	.42	.59	1

Livestock and Vegetation

The vegetation data for this study were measurements of standing crop, but did not account for growth, consumption, and other physical losses between sampling periods. The total amount of plant material actually available to livestock and pronghorns differed from the measured standing crop. Thus, it was not surprising that livestock, particularly sheep, density sometimes entered as a significant variable in predicting vegetation crops measured in the various pastures. For regressions with winter combined preferred forbs as the dependent variable, winter sheep density was the first variable to enter in a forward stepwise regression procedure. This indication of the impact of livestock on vegetation was reinforced by the fecal analysis results which showed overlap in use between livestock, particularly sheep, and pronghorns for forbs.

Another useful perspective on the competition for food between pronghorns and livestock is comparison of the food requirements for cattle and sheep in the different pastures at specific times with the availability of food as indicated by vegetation standing crop for the same season. Forbs were chosen for the comparison because of their importance in pronghorn diets.

Average daily forb intake for young and adult cattle, sheep, and pronghorns for each season was calculated (Table 21). The seasonal weight estimates for adults are based on information for range animals in New Mexico for each month (based on conversations with J. Sachse, J. Knight, and L. Foster, Extension Service, New Mexico State University) (see Table 21). Daily dry matter consumption as a percentage of body weight was based on information from range animals for cattle and sheep, and on information for goats of sizes similar to pronghorn (estimates provided by J. Holechek, Range Ecology, New Mexico State University). The percentage of forbs in the diet of each species was based on data from the fecal analysis portion of this study.

Table 21. Calculated seasonal forb consumption by cattle, sheep, and pronghorns.

	Cows				Calves			
	Sum	Fall	Win	Spr	Sum	Fall	Win	Spr
Weight (lbs)	875	925	975	900	140	350	500	700
(kg)	(398)	(420)	(443)	(409)	(64)	(159)	(227)	(318)
Daily intake %	2.2	2.0	1.8	2.0	2.4	2.2	2.0	2.2
% of forbs	21	31	14	17	21	31	14	17
Forbs consumed lbs/day	4.04	5.74	2.46	3.06	0.71	2.39	1.40	2.62
(kg)	(1.84)	(2.61)	(1.12)	(1.39)	(0.32)	(1.09)	(0.64)	(1.19)
	Ewes				Lambs			
Weight (lbs)	128	133	136	140	30	70	100	120
(kg)	(58)	(60)	(62)	(64)	(14)	(32)	(45)	(56)
Daily intake %	2.4	2.4	2.4	2.4	2.6	2.6	2.6	2.6
% forbs	48	58	44	44	48	58	44	44
Forbs consumed lbs/day	1.47	1.85	1.44	1.48	0.37	1.06	1.14	1.37
(kg)	(0.67)	(0.84)	(0.65)	(0.67)	(0.17)	(0.48)	(0.52)	(0.62)

	Pronghorns				Fawns			
Weight (lbs)	97	100	102	105	22	52	75	90
(kg)	(44)	(45)	(46)	(48)	(10)	(24)	(34)	(41)
Daily intake %	2.6	2.6	2.6	2.6	2.8	2.8	2.8	2.8
% forbs	82	75	69	70	82	75	69	70
Forbs consumed lbs/day	2.07	1.95	1.83	1.91	0.51	1.09	1.45	1.76
(kg)	(0.94)	(0.89)	(0.83)	(0.87)	(0.23)	(0.50)	(0.66)	(0.80)

For young animals, the same seasonal percentage of forbs in the diet as for adults was used, but weights were lower while daily intake as a percentage of body weight was higher than for adults. The results are considered to be a working estimate of demand on forbs by livestock for the study pastures.

For each pasture in each season of our study, the total forb demand by cattle and sheep combined for the whole season was calculated from stocking rates for that season, partitioned into young and adult animals, daily consumption of forbs for 91 days per season, and pasture size. The resulting forb demand by livestock in lbs/acre/season was compared to measured forb standing crop in lbs/acre/season. The resulting surplus of avilable forbs over forb demand by livestock (Table 22) shows that forb surplus was largest in the fall when forb production was greatest. Demand for forbs was sometimes greater than forb availability, particularly during the winter and spring of the dry periods of 1979-80 and 1981-82.

The surplus of forb availability over demand by cattle and sheep was correlated with total forb standing crop for each season. When the average seasonal forb surplus over all years for each pasture was examined with respect to the Viability Index for each pasture, the correlation between viability and average spring forb surplus was 0.62, of larger magnitude than the correlation between viability and ruggedness. The data indicate that the amount of available forbs is a significant factor in explaining the population trends for pronghorns in the study pastures.

The impact of the availability of forbs on pronghorn viability was illustrated by the different trends on the 3 adjacent pastures in the study, pastures 3-2, 3-5, and 3-6. All are large pastures located in the northwest portion of the study area and are similar in terms of ruggedness index, rainfall patterns, and general vegetation type. However, pronghorns in pasture 3-2 almost doubled the pool of breeding females, while populations in the other 2 pastures declined or stayed the same. While total forb production was not very different in the 3 pastures, the average number of fall forbs in pasture 3-2 was 17, compared to 12 and 11 for the other pastures. Additionally, average fall sheep stocking rate was only 3.8 animal units (19 sheep) per section in pasture 3-2 with the increasing pronghorn herd, in comparison with 12.3 and 9.3 animal units (62 and 47 sheep) per section pastures 3-5 and 3-6.

Table 22. Seasonal forb surplus calculated as forb standing crop minus seasonal forb demand by cattle and sheep (lbs/acre).

Pasture	win 79-80	spr 80	sum 80	fal 80	win 80-81	spr 81	sum 81	fal 81	win 81-82	spr 82	sum 82	fal 82
1-1	5	6	29	38	19	41	75	109	36	58	62	126
1-2	-10	-9	10	86	10	24	50	162	-8	-1	37	29
1-3	8	15	18	43	52	66	169	65	20	16	30	44
1-4	25	-1	12	70	--[a]	--	--	--	--	--	--	--
1-5	-10	-1	24	82	3	7	61	28	0	4	24	22
1-6	23	3	12	38	-6	-2	16	32	-8	-6	-6	1
2-1	-11	-1	10	5	-3	2	6	176	-10	3	-7	102
2-2	-11	-2	0	85	14	11	22	31	-14	-6	24	55
2-3	11	-7	10	73	33	43	24	90	21	27	13	155
2-4	-12	1	38	172	--[a]	--	--	--	--	--	--	--
2-5	-12	-1	11	102	0	3	9	64	1	-7	15	27
2-6	-3	5	10	77	27	43	51	17	12	8	27	44
3-1	-3	0	-3	68	--[a]	--	--	--	--	--	--	--
3-2	-7	5	41	52	21	-2	12	38	-5	20	8	32
3-3	-3	13	13	279	85	103	130	62	37	42	33	76
3-4	25	-5	23	163	1	14	82	81	9	-6	--	--
3-5	-8	2	13	38	1	9	30	8	6	21	44	24
3-6	-2	7	-7	83	4	11	26	8	-7	6	19	24

[a] Dropped from study due to low pronghorn numbers in the pasture.

Fawn Production by Pasture

The pattern of fawn production by pasture for each year was similar to that averaged over all pastures because of the importance of rainfall. Considering fawn production for each pasture for each of the 4 fawn crops of the study, spring rain alone accounted for about 15% of the observed variation. Inclusion of the variables for ruggedness and latitude increased the fraction of variation accounted for to 32%. Only those variables were available for anlaysis of data including the 1979 fawn crop, since vegetation studies did not begin until the winter of 1979-80. More detailed information was available on environmental conditions before and during the birth of the later 3 fawn crops produced during the study. Data on forbs, livestock, forb surplus, and pronghorn diets were examined. Single factors with correlation coefficients with maximum observed fawns per female of absolute value greater than 0.35 (Table 23) were useful indicators of fawn production for fall, winter, and spring. The standing crop of primary preferred forbs, and combined preferred forbs I & II were related to fawn production. However, the number of forb species in a pasture was more closely related to fawn production than the availability of preferred forbs. Several vegetation parameters were better than rainfall alone in indicating fawn production. Sheep density and forb surplus in the winter and spring also were important. Note that spring variables may be significant for newborn fawn survival as well as fawn production. Since fawns were not observed until June in this study, our measurement of fawn production actually represents a combination of fawn production and early survival, since fawns dying before the June overflight would not have been included in our production estimate.

The factors of ruggedness, pasture size, and latitude together account for approximately 30% of the variation in fawn production among pastures over the last 3 years of the study. The addition of fall and spring rainfall increases the fraction of explainable variation to 44%, and the addition of sheep density during the fall, winter, and spring increases it to 56%.

Table 23. Largest correlation coefficients of single parameters for pastures with pronghorn fawn production for 1979-82.

Fall parameters:	
0.43	combined preferred forbs I & II
0.36	preferred forbs I
0.37	rainfall
Winter parameters:	
0.39	forb surplus
0.41	combined preferred forbs I & II
-0.44	sheep density
0.43	number of forb species
0.36	preferred forbs I
Spring parameters:	
0.41	forb surplus
0.38	combined preferred forbs I & II
0.47	number of forb species

Vegetation information was not available for the fall prior to the birth of the 1980 fawn crop, but that information is probably picked up adequately by fall rainfall which was closely related to fall plant production in the years when both were measured. Rainfall data produced better regressions for fawn production than vegetation parameters alone, and addition of sheep stocking rates improved both sets of regressions. In general, higher fall and spring rainfall has been associated with higher fawn production, and higher sheep densities with lower fawn production. The addition of winter and spring forb surplus (available forbs minus livestock forb requirements), resulted in the regression presented in Table 24, in which coefficients for rainfall and forb surplus were positive, coefficients for sheep density were negative, and a substantial amount of the observed variation was explained.

Seasonal Survival Rates by Pasture

The pattern of seasonal pronghorn survival rates by pasture was not as closely related to the pattern averaged over all pastures as was the case for fawn production. The analysis of survival with respect to environmental variables focused on the fawn segment of each population, since fawn seasonal survival pattern was similar to that of adults, but with a greater variation in survival rates at any given time. No single factor was very closely related to fawn survival in the summer, fall or winter, but in the spring the correlation between fawn survival and sheep density was -0.46, and the correlation with percentage of forbs in pronghorn diets was 0.36. Correlations were run on

Table 24. Results of best regression of maximum observed fawns per female against environmental parameters from the fall, winter and spring before and during fawning, 1980-82.

Dependent variable: fawn production

Intercept: -0.00389

Independent variables:	Coefficients:
ruggedness index	-0.00070
pasture size in sections	0.03623
latitude index	0.05170
rainfall Sept. - Nov.	0.12423
rainfall March - May	0.06956
fall sheep density	-0.01436
winter sheep density	-0.02203
spring sheep density	-0.00775
winter forb surplus	0.00328
spring forb surplus	-0.00881
Regression	
Degrees of freedom	10
Sum of squares	5.49887
Mean	0.54983
Error	
Degrees of freedom	35
Sum of squares	3.62521
Mean	0.10357
Standard error of estimate	0.28703
F-value	5.30
Multiple R squared	60.2

data from each pasture each year for a given season.

Using the variables for ruggedness, rainfall, and same season total forbs, preferred forbs, numbers of forbs, livestock densities and forb surplus, it was possible to account for only 40% of the variation in fawn survival for each season. Again, analysis was based not on averages over years, but on data from all pastures and all years for each season. Fall variables were better predictors of winter fawn survival than were winter variables, again indicating the importance of fall rains and plant production for successful pronghorn herds. Ruggedness of the pasture was a consistently negative factor, as was sheep density. Inclusion of the variable for seasonal forb surplus was a significant improvement over either livestock rates or forb parameters alone.

Population Declines

During the course of the study, pronghorn herds abandoned or died out in 5 of the study pastures. An examination of the environmental conditions in each of those pastures during the times of rapid population decline serves to reinfoce the importance of ruggedness, rainfall, and sheep densities to fenced pronghorn herds.

The pronghorn herd in pasture 3-1 declined very abruptly during the winter of 1979-80, and the herd in pasture 1-4 declined during the following spring and summer. The period from fall 1979 through early summer 1980 was dry throughout the study area, but rainfall was even lower for these pastures than for the rest of the study area. The population in pasture 2-4, the most rugged pasture in the study, was lost when the animals jumped a cattle guard to enter an adjoining less-rugged pasture. The second most rugged pasture in the study group was pasture 2-5, where the pronghorn population declined slowly beginning in the summer of 1981 and was lost entirely during the second dry period ending in the spring of 1982. The population in pasture 3-4 declined rather rapidly in the winter and spring of 1982, coinciding with almost doubled sheep stocking rates. Through the summer of 1981, sheep stocking rates in pasture 3-4 varied from 10 to 20 AUs/sect (50 to 100 sheep/sect) (26 to 13 ha/AU), but by winter 1982 had been increased to 35 or 36 AUs/sect (7.4 to 7.2 ha/AU) or 165 to 170 sheep per section. During the winter or spring before the decline of each of these populations, forb demand by livestock exceeded forb availability.

Stocking Density

In examining the data from this study, the question of optimal stocking densities for starting new pronghorn herds has arisen. This study was not designed to answer that question, since all pastures were intitially stocked at the same density of approximately 2 pronghorns/section (130 ha/pronghorn). However, some partial conclusions can be drawn. First, 2 pronghorns/section (130 ha/pronghorn) is certainly a sufficient stocking density, since some of the herds in the study pastures increased very well from that starting point. Second, this study has not produced any evidence that higher stocking rates would be detrimental, since those herds that have done well have continued to increase in density. The herds that have declined can be explained without invoking density dependent declines. An initial stocking rate of 2 pronghorns/section (130 ha/pronghorn) certainly seems adequate; a higher initial pronghorn stocking rate would be acceptable biologically, but possibly not economically, since transplanting pronghorns is not a trivial procedure. However, results of this study indicate that anticipated sheep density, particularly stocking rates greater than 10 to 12 AUs/section (50 to 60 sheep/sect) (26 to 22 ha/AU), is a far more significant factor for pronghorn herd viability than is initial pronghorn density.

RECOMMENDATIONS

Task I: Fence Structures

1. In pastures with netwire fencing where adult cattle are the primary livestock, the horizontal grill or 4-strand barbed wire standard should provide adequate passages for pronghorns.
2. Calving pastures may require use of the modified horizontal grill, the 4-strand barbed wire standard or the net wire variation to restrict calves.
3. The modified horizontal grill is recommended for pastures enclosed with sheep-tight netwire when adult sheep are to be contained.
4. Lambing pastures require use of the 81.3 cm (32 in) net wire fence or the modified horizontal grill.
5. Selection of an area to place pronghorn passes is extremely important. Pasture use, shape, size and topography should be considered. Topographical features play an important role in

decreasing livestock exposure and increasing pronghorn exposure to the pass. Placement of passes near ridgetops will generally be more beneficial to pronghorn than placement of the structures in low areas. This placement also served to decrease livestock exposure to the pass. Passes should generally be placed in pasture corners or bends away from areas frequented by livestock. Placement of passes in corners or fence bends also works to funnel pronghorns into the pass area and thus increase pronghorn exposure. Placement of passes away from water sources, salting areas, livestock trails and vehicle routes can further reduce livestock exposure to passes.

Task II: Selection of Pastures Suitable for Pronghorns

1. The following model should be used to predict the viability of a stocked pronghorn herd in a pasture fenced with net wire:

$$VI = 1.082 + (0.106)(XI) - (0.006)(X2) - (0.068)(X3) - (0.059)(X4)$$

where: VI is Viability Index

X1 is number of forb species from fall vegetation survey

X2 is ruggedness index

X3 is pasture size in sections

X4 is anticipated average fall sheep stocking rate in animal units per section

The Viability Index can alternatively be interpreted as an index of suitability of the pasture for pronghorn populations.

Appendix V lists values of the Viability Index under various combinations of factors.

2. A decision on whether to stock any pasture with pronghorns will involve tradeoffs between the desirability and cost of stocking, and the risk of failure or probability of success of the herd as indicated by the value of the Viability Index for that pasture. Pastures with a Viability Index less than 1.0 should not be stocked with pronghorns. Pastures with a Viability Index greater than 1.5 have a high probability for maintaining successful herds under normal conditions.
3. Pronghorn stocking usually occurs in early spring; pronghorns should not be stocked in a spring following a dry winter or preceding a predicted dry year.
4. Initial stocking density for pronghorns on selected pastures should be 2 pronghorns/section (130 ha/pronghorn), with a sex ratio of about 3 females/male. Greater initial densities are acceptable, if the extra expense is acceptable.

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APPENDICES

APPENDIX I

Appendix 1. Size of range sites for each pasture in the study.

Pasture	Range Site	Size (acres)
1-1	PH-Pecos-Dev Assoc	342
	RH-Reakor-Pecos Assoc, loamy	739
	EcD-Ector-Rock outcrop 9 to 30 percent slope	1047
	EcC-Ector-Rock outcrop 0 to 9 percent slope	1592
1-2	24-Ector-Rock outcrop moderately steep	1573
	23-Ector-Rock outcrop moderately sloping	1595
1-3	BP-Bigetty-Pecos Assoc, loamy	682
	Lt-Lozier-Tencee complex	920
	PGB-Pecos silty clay loam	50
	Tg-Tencee-Upton complex	550
	RH-Reakor-Pecos Assoc, loamy	133
	PH-Pecos-Dev. Assoc	274
1-4	12 shallow-Deama Pastura Assoc.	288
	11 shallow, loamy-Pastura Harvey Assoc.	3,424
	14 shallow-Clovis Pastura Assoc.	183
1-5	40-Ector-Rock outcrop	443
	98-Ector-cougar Assoc	145

	95-Ector extremely cobbly loam	661
	108-Ector cobbly loam	1293
1-6	19 swale, loamy-Asparas La Fonda Assoc.	1,843
	12 shallow-Deama Pastura Assoc.	1,009
	13 shallow, loamy-Deama Harvey Assoc.	878
2-1	13 shallow, loamy-Deama Harvey Assoc.	6,013
2-2	21 shallow, gravelly-Hogadero-Pena Assoc.	1,967
	12 shallow-Deama Pastura Assoc.	1,195
	22 limestone hills-Deama Outcrop	2,184
2-3	16 shallow, loamy-Pastura Harvey Assoc.	235
	12 shallow-Deama Pastura Assoc.	2,931
	18 loamy, shallow-Pastura Harvey Assoc.	1,927
2-4	PH-Pecos Dev Assoc	499
	RH-Reakor-Pecos Assoc, loamy	159
	EcD-Ector-Rock outcrop 9 to 30 percent slope	3677
2-5	PH-Pecos Dev Assoc	468
	EcD-Ector Rock outcrop 9 to 30 percent slope	3970
2-6	13-Deama-Harvey Assoc	530
	21-Hogadero-Pena Assoc	1119
	12-Deama-Pastura Assoc	2537
	19-Asparas-Lafonda Assoc	1200
3-1	17 shallow-Pastura Partie Assoc.	2,250
	91 loamy, swale-Asparas La Fonda Assoc.	516
	90 shallow, gravelly-Hogadero-Pena Assoc.	139
	86 shallow-Deama Pastura Assoc.	6,796

3-2	18 loamy, shallow-Harvey Pastura Assoc.	1,094
	28 shallow-Deama Pastura Albinas Assoc.	7,057
	12 shallow-Deama Pastura Assoc.	549
	19 swale, loamy-Asparas La Fonda	229
3-3	UR-Upton-Reagan complex	236
	DP-Dev-Pima complex, loamy	88
	PM-Pima silt loam	333
	UG-Upton gravelly loam	208
	ER-Ector-Reagon complex	3964
	RA-Reagon loam	1617
3-4	Ecd limestone hills-Ector Outcrop	7,038
	RH loamy-Reaker Pecos Assoc.	313
	PH bottomland-Pecos Dev Assoc.	429
	EcC shallow-Ector Outcrop	1,369
3-5	22 limestone hills-Deama Rock Outcrop Assoc.	796
	21 shallow, gravelly-Hogadero-Pena Assoc.	658
	28 shallow-Deama-Pastura-Albinas Assoc.	2,355
	18 loamy, shallow-Harvey Pastura Assoc.	3,458
	12 shallow-Deama-Pastura Assoc.	2,495
3-6	19 swale, loamy-Asparas La Fonda Assoc.	337
	21 shallow, gravelly-Hogadero-Pena Assoc.	103
	18 loamy, shallow-Harvey-Pastura Assoc.	2,220
	28 shallow-Deama-Pastura-Albinas Assoc.	3,965
Gist Ranch		
1	RH loamy-Reakor-Pecos Assoc.	828
	EcC shallow-Ector Rock Outcrop	1,762
	UA breaks-Upton-Atoka Assoc.	193

	lt gravelly-Lozier-Tencee complex	1,083
	PH bottomland-Pecos Dev Assoc.	797
2	RH loamy-Reakor-Pecos Assoc.	424
	lt gravelly-Lozier-Tencee complex	706
3	RH loamy-Reakor-Pecos Assoc.	393
	lt gravelly-Lozier-Tencee complex	788
4	BP salt flats-Bigetty-Pecos Assoc.	1,758
	TG gravelly-Tencee-Upton complex	264
	Lt gravelly-Lozier-Tencee complex	2,280
	PGB bottomland-Pecos Silty clay loam	40
	UA breaks-Upton-Atoka Assoc.	183
	RH loamy-Reakor-Pecos Assoc.	496
5	RH loamy-Reakor-Pecos Assoc.	1,546
	Lt gravelly-Lozier-Tencee complex	915
	BP salt flats-Bigetty-Pecos Assoc.	25
	UA breaks-Upton-Atoka Assoc.	33
6	PGB bottomland-Pecos Silty clay loam	96
	EcD limestone hills-Ector Rock Outcrop	138
	PH bottomland-Pecos Dev Assoc.	126
	Lt gravelly-Lozier-Tencee complex	1,594
	RH loamy-Reakor-Pecos Assoc.	626
	EcC shallow-Ector Rock Outcrop	189
Circle F	12A loamy, swale-Asparas La Fonda Assoc.	387
#1	12 shallow, gravelly-Hogadero-Pena Assoc.	4,648
Circle F	11 shallow, loamy-Pastura Harvey Assoc.	213
#8	22 limestone hille-Deama Outcrop	397
	12 shallow, gravelly-Hogadero-Pena Assoc.	4,208

SP-Johnson	EcC-Ector -Rock outcrop	2546
#1	0 to 9 percent slope	
	PH-Pecos-Dev Assoc	547
#2	EcC-Ector-Rock outcrop	5158
	0 to 9 percent slope	
	RH-Reakor-Pecos Assoc, loamy	337
	PH-Pecos-Dev Assoc	206

APPENDIX II

Appendix 2. Relative frequency values, as determined by fecal analysis, of the major (≥1.0%) plant taxa in the diets of cattle (C), pronghorns (P), and/or sheep (S) in east-central New Mexico, fall 1979 through fall 1982. An additional 160 taxa occurred in lesser amounts.

Species	Fall (4)			Winter (3)			Spring (3)			Summer (3)		
	C	P	S	C	P	S	C	P	S	C	P	S
GRASSES												
Aristida spp.	4.7	0.3	1.7	6.9	0.2	1.9	5.5	0.4	2.8	11.1	0.6	3.1
Bouteloua curtipendula	6.3	0.3	6.4	6.5	0.1	4.0	5.7	0.1	4.9	6.1	0.1	5.7
B. eriopoda	4.0	0.1	2.3	3.7	0.0	2.2	3.2	0.1	2.6	2.0	0.1	1.9
B. gracilis	18.9	3.2	9.7	17.7	1.2	11.8	16.7	1.0	11.4	9.9	1.8	10.9
B. hirsuta	2.2	0.0	1.4	2.4	0.1	2.6	1.6	0.0	1.3	2.3	0.4	2.4
Chloris spp.	1.9	0.1	0.0	0.8	0.1	1.5	1.2	0.1	0.1	1.7	0.0	0.9
Erioneuron pilosum	0.2	0.1	0.1	2.3	0.1	1.0	2.6	0.2	0.7	3.5	0.1	1.7
Hilaria jamesii	1.0	0.0	0.2	0.3	0.0	0.1	0.2	0.1	0.3	2.4	0.1	0.8
H. mutica	1.2	0.1	0.2	1.4	0.1	0.1	0.8	0.1	0.2	2.7	0.1	2.4
Lycurus phleoides	0.4	0.1	0.3	5.0	0.1	9.1	4.3	0.1	4.2	4.5	0.1	4.9
Muhlenbergia spp.	0.5	0.1	0.1	6.9	0.2	3.6	6.7	0.3	4.1	3.5	0.1	3.3
Scleropogon brevifolius	0.1	0.0	0.2	1.1	0.0	0.2	2.0	0.2	1.4	0.7	0.1	0.6
Setaria spp.	0.5	0.1	0.2	0.7	0.0	0.2	0.8	0.1	1.1	0.6	0.0	0.2

Appendix 2. Continued.

Species	Fall (4)			Winter (3)			Spring (3)			Summer (3)		
	C	P	S	C	P	S	C	P	S	C	P	S
S. leucopila	0.2	0.1	0.1	1.9	0.1	2.0	1.1	0.1	1.0	1.8	0.1	0.7
Sorghastrum avenaceum	0.6	0.0	0.2	1.3	0.0	1.1	1.2	0.2	0.1	1.2	0.1	0.6
Sporobolus spp.	0.5	0.1	0.4	8.0	0.5	6.4	11.2	1.2	9.3	20.2	0.4	10.7
Stipa spp.	0.4	0.1	0.2	7.7	0.3	4.8	9.5	0.3	3.3	4.4	0.2	2.1
FORBS												
Abutilon incanum	0.1	2.0	2.3	0.2	0.1	0.1	0.1	0.3	0.1	0.9	1.2	0.6
Ambrosia psilostachya	0.1	1.1	0.3	0.3	3.8	0.4	0.2	2.0	0.7	0.1	1.7	0.3
Artemisia lucovicana	1.1	9.8	7.0	0.9	1.0	4.0	0.1	3.8	1.5	0.4	6.1	1.4
Berlandiera lyrata	1.6	3.5	2.5	0.1	3.2	0.7	0.1	2.5	1.3	0.0	4.4	0.9
Calyophus serrulatus	2.1	1.6	1.8	0.1	0.6	0.3	0.1	1.1	0.4	0.3	5.7	1.5
Conyza coulteri	0.6	2.1	3.0	0.5	2.0	1.2	0.3	1.8	1.6	1.9	1.5	1.5
Croton spp.	14.7	17.9	9.5	1.7	7.0	4.2	1.2	4.1	2.0	4.7	7.0	7.8
Descurainia pinnata	0.0	0.1	0.1	0.1	0.5	0.0	0.1	1.1	0.1	0.0	0.0	0.0
Erigeron spp.	0.1	0.1	0.1	0.0	0.5	0.0	0.1	0.6	0.1	0.0	1.0	0.3
Eriogonum spp.	0.1	4.2	4.5	0.3	4.8	4.3	0.1	3.3	1.1	0.1	5.2	3.0

Appendix 2. Continued.

Species	Fall (4)			Winter (3)			Spring (3)			Summer (3)		
	C	P	S	C	P	S	C	P	S	C	P	S
Euphorbia spp.	0.6	0.8	0.6	0.1	0.3	0.0	0.1	0.5	0.1	0.1	2.4	0.4
Evax verna	0.2	2.7	0.7	0.1	0.2	0.0	0.0	0.3	0.2	0.1	1.5	0.2
Evolvulus nuttialianus	0.0	1.8	0.5	0.0	0.1	0.1	0.0	0.1	0.0	0.1	2.5	1.4
Froelichia floridana	0.2	1.2	0.7	0.1	0.3	0.1	0.1	0.1	0.2	0.0	0.1	0.3
Gallium microphyllum	0.1	0.8	0.8	0.1	2.3	0.6	0.1	2.5	0.5	0.0	0.2	0.0
Hedeoma spp.	0.0	0.1	0.2	0.0	0.3	0.1	0.0	1.0	0.2	0.0	0.2	0.1
Hedyotis spp.	0.2	0.2	0.5	0.0	0.0	0.1	0.0	1.1	0.0	0.1	0.0	0.3
Krameria lanceolata	0.1	0.9	0.6	0.5	0.8	0.6	0.4	0.8	5.7	0.1	1.0	0.5
Lesquerella spp.	0.0	2.5	3.8	0.0	0.2	0.1	0.0	0.3	0.4	0.0	0.0	0.0
L. fendleri	0.1	2.2	2.8	0.9	8.2	2.8	2.0	10.3	7.1	0.1	0.6	1.5
Leucelene spp.	0.2	0.1	0.2	0.1	4.8	0.5	0.1	3.0	0.6	0.0	0.4	0.0
Linum spp.	0.0	0.1	0.1	0.1	2.0	0.1	0.2	0.6	0.6	0.1	0.5	0.2
L. rigidum	0.0	0.3	0.2	0.0	0.5	0.0	0.0	0.1	0.0	0.0	1.0	0.0
Marrubium vulgare	1.7	0.3	1.0	0.7	0.6	0.5	1.1	1.6	3.3	0.3	0.6	1.2
Melampodium leucanthum	2.1	1.2	0.4	0.1	0.7	0.2	0.3	0.7	0.2	0.1	1.3	0.4

Appendix 2. Continued.

Species	Fall (4)			Winter (3)			Spring (3)			Summer (3)		
	C	P	S	C	P	S	C	P	S	C	P	S
Mentzelia spp.	0.3	0.5	0.1	0.1	0.3	0.2	0.1	0.1	0.0	0.1	1.0	0.1
Oenthera spp.	0.1	0.7	0.5	0.1	0.2	0.1	0.1	1.3	0.1	0.1	0.3	0.6
Plantago patagonica	0.2	1.4	1.4	0.1	2.1	0.6	0.1	2.5	0.6	0.1	1.7	0.7
Polygala spp.	0.1	2.3	0.6	0.4	2.6	0.4	0.1	2.2	0.7	0.1	1.3	0.1
Ratibida columnaris	0.1	2.0	0.8	0.0	0.4	0.2	0.0	0.2	0.1	0.1	1.6	0.1
Salvia sp.	0.0	1.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0
Sida spp.	1.9	1.8	1.6	0.0	0.1	0.1	0.2	0.0	0.0	0.1	1.1	0.3
Solanum elaegnifolium	3.3	1.1	0.5	0.5	1.0	1.5	0.1	1.0	0.9	0.1	2.9	0.8
Sphaeralcea angustifolia	4.6	1.3	2.3	1.0	1.9	0.4	0.8	0.1	1.1	1.5	0.9	0.4
S. coccinea	2.8	4.1	3.0	0.6	1.6	2.6	0.9	0.1	1.7	1.3	6.2	4.8
Verbena spp.	0.2	0.2	0.1	0.8	0.2	1.0	1.3	1.7	1.8	0.2	0.7	0.1
Zinnia grandiflora	0.5	1.2	0.4	0.1	0.6	0.1	0.1	0.1	0.1	0.1	0.6	0.5
BROWSE												
Artemisia bigelovi	0.0	0.0	0.0	0.2	0.8	0.1	0.0	1.1	0.7	0.1	0.8	0.2
A. filifolia	0.1	1.5	0.5	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1

Appendix 2. Continued.

Species	Fall (4)			Winter (3)			Spring (3)			Summer (3)		
	C	P	S	C	P	S	C	P	S	C	P	S
Brickella brachyphylla	0.0	1.7	1.3	0.0	1.6	0.6	0.0	1.3	0.0	0.0	0.7	0.1
Dalea formosa	0.2	0.4	1.9	0.4	0.8	0.6	0.1	0.6	0.2	0.1	6.6	0.5
Eurotia lanata	2.0	0.1	2.6	0.1	1.6	0.0	0.2	0.2	0.1	0.3	0.1	1.2
Fallugia paradoxa	0.1	0.6	0.6	0.2	0.9	0.4	0.1	1.0	0.2	0.1	0.4	0.6
Gutierrezia sarothrae	0.3	2.2	0.2	0.1	11.7	2.5	0.4	6.9	0.7	0.0	0.5	0.1
Juniperus spp.	0.3	0.0	0.0	0.1	4.9	0.0	0.0	1.5	0.0	0.0	0.0	0.0
Krameria parviflora	0.1	0.3	0.5	0.1	0.3	0.1	0.2	0.2	0.3	0.0	1.7	0.4
Nolina microcarpa	0.0	0.1	0.2	3.6	0.4	0.4	4.4	1.0	1.2	1.0	0.7	0.5
Opuntia spp.	4.1	7.0	0.6	3.6	9.9	2.8	3.6	7.9	3.6	0.8	1.7	0.1
Proposis glandulosa	0.1	0.9	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	1.0	0.0
Quercus undulata	0.0	1.2	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.2
Rhus aromatica	0.0	0.3	0.6	0.0	1.6	0.1	0.1	1.2	0.4	0.0	0.8	0.3
Rhus microphylla	0.2	2.3	1.3	0.6	2.6	0.3	0.4	1.2	0.2	0.0	3.7	1.9

APPENDIX III

Appendix 3. Maximum observed fawns per female and seasonal fawn survival, for the 18 study pastures, 1979-82.

	June 1979 - May 1980				
	Fawns/	Fawn survival			
Pasture	female	Sum	Fall	Win	Spr
1-1	1.44	1.00	1.00	1.00	1.00
1-2	1.67	.70	1.00	1.00	.71
1-3	1.17	1.00	.86	1.00	.83
1-4	.80	1.00	.75	.67	1.00
1-5	.67	1.00	.75	.67	1.00
1-6	1.17	1.00	1.00	.86	1.00
2-1	.64	1.00	1.00	.78	1.00
2-2	1.00	1.00	.83	1.00	.70
2-3	1.09	1.00	.92	.64	1.00
2-4	.56	.40	1.00	1.00	1.00
2-5	.55	1.00	1.00	1.00	1.00
2-6	.82	1.00	.89	.88	1.00
3-1	.78	.86	.92	.18	1.00
3-2	1.29	1.00	1.00	1.00	1.00
3-3	1.18	1.00	.90	1.00	1.00
3-4	.68	1.00	1.00	.92	1.00
3-5	.80	1.00	.81	1.00	1.00
3-6	1.11	1.00	1.00	.95	1.00

June 1980 - May 1981

1-1	1.22	.64	.86	.83	1.00
1-2	.83	1.00	.40	1.00	1.00
1-3	1.00	1.00	.50	1.00	1.00
1-4	0	--	--	--	--
1-5	.40	1.00	1.00	.50	1.00
1-6	0	--	--	--	--
2-1	.17	.50	0	--	--
2-2	.22	1.00	1.00	1.00	1.00
2-3	0	--	--	--	--
2-4	0	--	--	--	--
2-5	.30	1.00	.67	.50	1.00
2-6	.30	.50	.75	1.00	1.00
3-1	0	--	--	--	--
3-2	.12	.50	1.00	1.00	0
3-3	1.35	.30	1.00	.86	1.00
3-4	1.20	.28	.06	1.00	.67
3-5	.63	.70	.71	.60	1.00
3-6	.71	1.00	.58	1.00	1.00

June 1981 - May 1982

1-1	.87	1.00	.85	1.00	1.00
1-2	.50	1.00	1.00	.67	.50
1-3	1.00	1.00	1.00	1.00	1.00
1-4	--	--	--	--	--
1-5	1.17	1.00	.86	1.00	1.00
1-6	.27	.67	1.00	1.00	1.00
2-1	.20	1.00	1.00	.50	0
2-2	.73	1.00	.25	1.00	1.00
2-3	.25	1.00	1.00	1.00	1.00
2-4	--	--	--	--	--
2-5	1.14	.25	0	--	--
2-6	1.86	1.00	.81	1.00	1.00
3-1	--	--	--	--	--
3-2	1.00	1.00	1.00	1.00	1.00
3-3	1.07	.97	.73	1.00	1.00
3-4	.82	.67	.33	1.00	0
3-5	.94	.80	.92	.73	.88
3-6	.83	1.00	.85	.82	.86

June 1982 - Aug. 1982

1-1	.88	1.00	--	--	--
1-2	.80	1.00	--	--	--
1-3	1.00	1.00	--	--	--
1-4	--	--	--	--	--
1-5	.60	1.00	--	--	--
1-6	0	--	--	--	--
2-1	0	--	--	--	--
2-2	.17	1.00	--	--	--
2-3	.83	1.00	--	--	--
2-4	--	--	--	--	--
2-5	--	--	--	--	--
2-6	.60	1.00	--	--	--
3-1	--	--	--	--	--
3-2	.33	1.00	--	--	--
3-3	.81	1.00	--	--	--
3-4	0	--	--	--	--
3-5	.45	1.00	--	--	--
3-6	.11	1.00	--	--	--

APPENDIX IV

Appendix 4. Forbs with high importance values in pronghorn diets as determined from fecal data analysis.

Preferred forbs Group I

- Abutilon incanum
- Artemesia ludoviciana
- Berlandiera Lyrata
- Calylophus serrulata
- Croton spp.
- Eriogonum spp.
- Krameria lanceolata
- Sphaeralcea angustiflolia
- Sphaeralcea coccinea

Preferred forbs Group II

- Ambrosia psilostachya
- Astragalus spp.
- Conyza coulteri
- Dalea jamesii
- Erodium spp.
- Euphorbia spp.
- Evax verna
- Froelichia spp.
- Gallium microphyllum
- Heterotheca spp.
- Lesquerella fendleri
- Lithospermum spp.
- Marrubium vulgare
- Plantago patagonica
- Polygala spp.
- Ratibida columnaris
- Solanum spp.
- Verbena spp.
- Zinnia grandiflora

APPENDIX V

Appendix 5. Pasture suitability or Viability Index values for pastures with selected size, ruggedness, sheep stocking and fall forb characteristics. (For other combinations of parameters, index values can be interpolated from this table or calculated from the model presented in the Recommendations section.)

		Pasture size: 5 sections				
Ruggedness index	Sheep AU/ sec/yr	No. of forb species in the fall				
		5	10	15	20	30
33	0	1.1	1.6	2.1	2.7	3.7
	5	0.8	1.3	1.8	2.4	3.4
	10	0.5	1.0	1.5	2.1	3.1
	20	--	0.4	1.0	1.5	2.5
	30	--	--	0.4	0.9	2.0
66	0	0.9	1.4	1.9	2.5	3.5
	5	0.6	1.1	1.6	2.2	3.2
	10	0.3	0.8	1.3	1.9	2.9
	20	--	0.2	0.8	1.3	2.3
	30	--	--	0.2	0.7	1.8
100	0	0.7	1.2	1.7	2.3	3.3
	5	0.4	0.9	1.4	2.0	3.0
	10	0.1	0.6	1.1	1.7	2.7
	20	--	0.0	0.6	1.1	2.1
	30	--	--	0.0	0.5	1.6
133	0	0.5	1.0	1.5	2.1	3.1
	5	0.2	0.7	1.2	1.8	2.8

	10	--	0.4	0.9	1.5	2.5
	20	--	--	0.4	0.9	1.9
	30	--	--	--	0.3	1.4

Pasture size: 10 sections

33	0	0.7	1.3	1.8	2.3	3.4
	5	0.4	1.0	1.5	2.0	3.1
	10	0.1	0.7	1.2	1.7	2.8
	20	--	0.1	0.6	1.1	2.2
	30	--	--	0.0	0.6	1.6
66	0	0.5	1.1	1.6	2.1	3.2
	5	0.2	0.8	1.3	1.8	2.9
	10	--	0.5	1.0	1.5	2.6
	20	--	--	0.4	0.9	2.0
	30	--	--	--	0.4	1.4
100	0	0.3	0.9	1.4	1.9	3.0
	5	0.0	0.6	1.1	1.6	2.7
	10	--	0.3	0.8	1.3	2.4
	20	--	--	0.2	0.7	1.8
	30	--	--	--	0.2	1.2
133	0	0.1	0.7	1.2	1.7	2.8
	5	--	0.4	0.9	1.4	2.5
	10	--	0.1	0.6	1.1	2.2
	20	--	--	0.0	0.5	1.6
	30	--	--	--	0.0	1.0

			Pasture size: 15 sections			
33	0	0.4	0.9	1.5	2.0	3.0
	5	0.1	0.6	1.2	1.7	2.7
	10	--	0.3	0.9	1.4	2.5
	20	--	--	0.3	0.8	1.9
	30	--	--	--	0.2	1.3
66	0	0.2	0.7	1.3	1.8	2.8
	5	--	0.4	1.0	1.5	2.6
	10	--	0.1	0.7	1.2	2.3
	20	--	--	0.1	0.6	1.7
100	0	0.0	0.5	1.1	1.6	2.6
	5	--	0.2	0.8	1.3	2.3
	10	--	--	0.5	1.0	2.1
	20	--	--	--	0.4	1.5
	30	--	--	--	--	0.9
133	0	--	0.3	0.9	1.4	2.4
	5	--	0.0	0.6	1.1	2.1
	10	--	--	0.3	0.8	1.9
	20	--	--	--	0.2	1.3
	30	--	--	--	--	0.7

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